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CUTANEOUS AND KINAESTHETIC SENSES

BY JOHN T. METCALF
University of Vermont

The most important single contribution that has appeared in the period covered by this review is that of Katz (48). His study is one of the most comprehensive in recent years. It differs markedly from the majority of contemporary studies in that it devotes itself to a qualitative analysis of what most other authors would regard as relatively complex experiences, instead of attempting a minute analysis of finer elements. The author justifies this divergence in viewpoint and method on the ground that it is better to study touch experiences as they actually occur in life, rather than to make minute analyses under conditions which must of necessity be artificial. The resulting study is highly stimulating and suggestive, but the reviewer will not take further account of it here. Many of the facts reported lie outside the scope of this review, and the work has recently been given a special review in this BULLETIN by Ziegler.[1]

Stetson (86) has carried out an investigation to determine whether or not the hair follicle is a sense organ of pressure. This was done in two ways: (1) The neural endings of follicles were removed and the sensitivity of the hair and surrounding areas tested, and (2) areas denuded of follicles were tested for their pressure sensitivity. The experiment required, of course, a very fine technique. The anterior portion of the scrotum was chosen as the area on which to work, because the hairs are sparse and the follicles large. By minute operations the upper or lower parts, or both, of the follicles were removed,

[1] See this BULLETIN, 1926, 23, 326–336.

and the touch sensitivity of hairs and adjacent skin tested. Removal of the lower innervation of the follicle had no effect upon sensitivity; removal of the upper innervation reduced it slightly. Removal of all the follicles in an area did not change power of localization in the area or sensitivity to pressure. Confirmatory results were obtained in the investigation of scars of long standing.

Franz (13) reports an investigation of the pressure threshold, in which the chief interest centers upon the statistical method used. Instead of determining thresholds for single pressure-spots he takes a given skin area of 4 sq. cm. and applies stimulus-hairs of different strength, each one 50 times. The threshold for the area is then determined on the basis of the percentage of times stimuli of different strength resulted in sensation. The thresholds obtained in this way are found to correspond well to those obtained by earlier investigators working on single pressure-spots. The author believes that this method will be useful in the investigation of subjects untrained in introspection. He uses it himself in the study of pathological cases with pressure-sense disturbances. The method is also used by Stein (83, 85) in a study of the tendency of the pressure threshold to fluctuate in pathological cases of sensory disturbance. From this study Stein concludes that holding the pressure threshold constant is a special function of the pressure-sense. He finds this function disturbed in various ways in pathological conditions. Halpern's study (39) is somewhat related to these in subject. This author follows the effect upon the pressure threshold of induced hyperaemia. The first effect is a fall, but this soon gives way to the opposite effect, and the threshold rises above normal.

Klemm (51) studies the effect of giving two touch stimuli separated by a very small time interval, far below the time threshold. The difference in time is not, of course, perceived as such, but the results show that it has an effect. If the stimuli are applied to the skin close enough to each other to be below the spatial threshold, there is a tendency to localize the combined impression in the direction of the stimulus which is first given. Other interesting results are obtained by applying stimuli separated by minute time intervals to parts more or less remote from each other in space.

Henry (42) and Courtier (9) report experiments on a supposed form of tactual sensitivity hitherto unknown. The first of these authors suggests that the field of touch sensibility is much more extended than current psychobiology supposes. He holds that subjects may be more sensitive to the duration of atomic vibrations than

to their speed, or *vice versa*. He has developed a method of testing this, using equal weights of six different substances which vary in these characteristics. Preliminary experiments are reported by Courtier, and while the results are admittedly meager, the author is convinced that the kind of sensitivity described by Henry actually exists.

v. Skramlik (82) makes an introspective analysis of tactual perception, not only of objects in the outside world but also of parts of one's own body. When, say, the finger touches a solid surface one does not perceive the surface as unyielding and the finger as flattening. Rather the finger seems to sink into the surface. This the author attributes to one's failure to take account of the change in the normal contour of the skin of the finger. The normal is found when the finger hangs free in the air. When two parts of the body touch each other the one with the lower spatial sensitivity seems to be deformed by the other. If the two parts are equal in spatial sensitivity, attention determines which part perceives the other. Similar results were obtained from experiments and observations in which the parts of the body were moved in touching. Another study in which the rôle of attention is subjected to analysis is that of Newhall (63). This author investigates the effect of attention upon the intensity of the sensation aroused by a pressure stimulus of given strength. The chief difficulty seemed to be to find a method of controlling the direction or degree of attention. Several of the methods tried were found adequate, and each resulted in an increase in the intensity of sensation when attention was directed to it. The stimuli were given by means of a pressure-balance, which not only controlled accurately the amount of pressure and its duration, but also provided a gradual release, an important point because the release of pressure sometimes gives rise to a second sensation.

Interest in the validity of Weber's Law for pressure was stimulated a few years ago by the differing results obtained by Hansen, working with v. Frey, and Gatti, a pupil of Kiesow. Each of these investigators used touch hairs of varying strength, and worked on a single pressure-spot. Gatti's results conformed to Weber's Law, Hansen's did not. Kiesow's article (49) considers this discrepancy of results. He had Gatti repeat his experiments, working on a different area where touch-spots were less dense and the likelihood of the effect of the stimulus spreading to neighboring pressure-points consequently less. These experiments further supplement the earlier ones in that now a hair-point is worked on, while then it was a

pressure-point on a hairless surface. The average relative threshold of 1/7 confirms the earlier results, and its constancy here, as before, supports the validity of Weber's Law. Kiesow thinks that the differing results of Hansen and Gatti must be due to differences in experimental conditions. He rejects v. Frey's suggestion that conformity to Weber's Law is due to extensive rather than to intensive changes as not being applicable to the conditions of Gatti's experiment. Gatti's own more extended reports in Italian have unfortunately not been available to the reviewer.

Schriever (79) attacks this problem anew, using even finer stimuli consisting of hard-rubber and steel points applied with Pauli's stimulus-lever apparatus. In general the results, like Gatti's, conform to Weber's Law, the relative difference thresholds being fairly constant except for the low values. The study of Pauli and Wenzel (67), in so far as it bears directly on this problem, also supports the validity of Weber's Law. Deviations from Weber's Law, the authors believe, are to be attributed to the effects of accessory factors. The deviation, for example, in the case of stimuli of low intensity they explain as being due, among other things, to the difficulty of perceiving and comparing weak sensations. The average relative difference threshold found by these authors, about one-fifth, corresponds fairly well with those found by Hansen and Gatti. The work of Pauli and Wenzel is incidental to a more extended general study of Weber's Law, in which they give reasons for a physiological rather than a psychological interpretation, and relate it to the principle of relativity.

Another confirmation of Weber's Law for pressure comes from a study by Nosske (64) of experimental data obtained by Kraepelin over thirty years ago, but never before worked over and published. The values of the relative difference thresholds are fairly constant, though they grow smaller with the heavier weights. The relative threshold, as was to be expected, is much lower than that obtained by recent investigators working on single pressure-points.

Chiba (8) finds that an increase of weight is more readily and accurately perceived than a decrease. This asymmetry he relates to a number of other forms of asymmetry in mental activity, and he explains it as a phenomenon of contrast in which attention plays a prominent part. After the normal stimulus is given the attention goes on to the comparison stimulus, if this is greater than the first. In case it is less, the attention turns back to the normal stimulus, making the comparison more difficult and less certain than in the first case.

Weber's Law is also studied by Bush and Austin, (6) who increase the stimulus by flowing increments. Sand was found badly adapted to this purpose, so the investigators used water. Two sets of experiments were made. In the first the beaker of water, which was to be modified by the addition of the flowing increment, rested on the palm of the hand, the hand in turn resting on cotton. In the second set the hand was supported from the wrist only, giving tendon tension in addition. Four different rates of flow of the water were used. The results do not conform to Weber's Law and they do indicate that, under the conditions, the threshold is influenced by the time element in the stimulus, *i.e.*, the rate at which the increments of weight are added. Löwi's study (59) has to do with the more complex mental processes involved in the obtaining of a threshold.

The question of the existence of a deep cutaneous pressure sense is one which has received a good deal of attention recently. Von Frey holds that such a sense does not exist. Goldscheider holds that while the true pressure sense is the superficial one, there is a somewhat imperfect deep sensibility. Von Frey brings forward further support for his view from the researches of some of his pupils. One of them, Rein, has developed a new method of local anesthesia by which the anesthetizing liquids are introduced into the skin by electric endosmosis (73, 74). This method proved so successful, and such an improvement upon earlier means of anesthetizing the upper layers of the skin, that it was applied by v. Frey, Rein, and Strughold (21) to the problem of the existence of a deep pressure sense. On the anesthetized area of the skin (20 to 64 sq. cm.) pressure thresholds are found to be increased several hundred or even several thousand fold when the stimulus is applied to the center of the area. The effect of pulling the skin up by means of an attached fine silk thread is compared with pressure, and it is found that the effect is the same. By means of a binocular magnifying glass the deformation of the skin at the edge of the anesthetic area is observed and measured when pressure or pull is exerted. Such a deformation was actually found, confirming v. Frey's contention that whatever sensibility there is under these conditions is the result of conduction to active superficial receptors outside the insensitive area by deformation of the skin. The effect of exerting pull tangential to the skin surface was also tried. A small metal plate provided with a hook was stuck to the skin. A fine thread from the hook was run over a wheel to the stimulating apparatus. Thresholds were determined for pressure downward on the plate in the normal way, and for force exerted on

the plate in the tangential direction. 70 g. force was required in the first arrangement and only 12 g. in the second. Confirmatory evidence was obtained in the study of a clinical case reported by v. Frey (15, 16) in connection with a general discussion of the significance of these findings. He holds that the separation of the pressure sense into superficial and deep components is not justified.

The article by Goldscheider and Hoefer (33) on the pressure sense confines itself to the problems of deep sensitivity. Their experiments are carried out by means of a stimulating lever applied to the skin, first in its normal condition and then treated in various ways to eliminate superficial sensitivity. Under the latter condition the authors find a deep sensation of pressure, rather dull, and seeming to come from within rather than from without. When the pressure is applied above a bone the element of hardness is lacking, which confirms the authors in the opinion that the sensation arises from the cutis and not from the bone. However, a needle stuck through anesthetized skin into the periosteum aroused a sensation which resembled pressure until, with increased force, it went over into pain. These authors reject v. Frey's theory of conduction by skin deformation, giving a series of eight observations which tell against it. Hausmann (40) agrees with Goldscheider in this, and he argues for the existence of a deep pressure sense. In this connection he considers why it is not possible to feel the radial pulse with the tongue (41). Lehmann (54) finds that when superficial sensibility is absent in clinical cases pressure is nevertheless experienced, and often as intensely painful. He relates his own results to Head's and as an explanation of them he favors the idea of a disturbance through injury of the normal coöperation between two systems. Davis (10) finds deep sensibility in the face in the form of pressure pain, though all superficial sensibility is lost following trigeminal neurectomy.

Von Frey, with his pupil Felix, has made a careful study of tickle (12). These authors point out the need of making a careful distinction between skin tickle and deep tickle. They are concerned with the former, and would find out how it is to be distinguished from itch, and how it is related to the other cutaneous qualities. Tickle is found to have a much lower threshold than itch, and a much quicker reaction time. Also, itch sensations usually last a long time, while sensations of tickle do not. The reflexes appropriate to these two forms of sensation are different, scratching belonging to itch and shuddering to tickle. Further experiments convince the authors that tickle is mediated by the touch receptors, especially the hairs. They

cocainized the skin, greatly reducing its sensitivity to pain, and found tickle unaffected. Also, one of them had a case of sunburn, and it was found that tickle could be aroused on the already itching skin. The relationship of tickle to the other qualities of the touch sense the authors regard as an important problem which deserves further investigation. Von Frey recurs to this question in several other papers (14, 17, 18, 19) in which he develops the view that the same receptors mediate four different forms of sensation, touch (Berührung), tickle (Kitzel), vibration (Schwirren), and pressure (Druck). This, he admits, goes against a strict interpretation of the doctrine of specific nerve energies. He holds, however, that his view may be reconciled with this doctrine if one thinks of nervous processes as undergoing modification by combination with others on the way from the periphery to the point at which physiological processes eventuate in psychic ones. This idea of elements combining and coming to consciousness as a more elaborate whole he relates to the Gestalt theory, pointing out that for a test of the latter's validity no sense field is better adapted than the cutaneous. Somewhat similar views are developed by v. Weizsäcker (101) on the basis of clinical and experimental study of pathological cases.

Goldscheider (26) presents a theory of tickle, basing it upon the similarity between tickle and the sensation of vibration. He thinks of each of these sensations as the result of an oscillatory process set up in the nerves sensitive to mechanical stimulation. When the oscillations are of sufficient amplitude and slowness to be perceived separately, the result is the sensation of vibration. When they are more rapid and of smaller amplitude the result is tickle. Itch is considered in the same article, and is regarded, like pain, as a phenomenon of summation. Kroner (53) gives reasons for regarding itch as the result of a disturbance of the blood vessel system of the skin. He believes that nerve fibers are involved which connect the skin directly with the autonomic system. Drechsel (11) experiments with the galvanic current. Making the cathode very small (5/1,000 sq. mm.), and applying it so lightly as not to stimulate the skin mechanically, he succeeds in arousing sensations of vibration when the cathode is applied to a pressure spot; sensations of itch, burn, or prick when it is applied elsewhere. Repetition seems to lower the resistance of the skin and strengthen the effect. The articles by Fröschels (22) and Kompanejetz (52) have to do with a symptom first observed by the former. In otosclerosis and deaf-mutism the normal ticklishness

of the external auditory canal is found to be entirely lacking, or very greatly reduced.

Several topographical studies of one or the other of the temperature senses have appeared from v. Frey's laboratory. In a study of the density of the warmth points on different regions of the body Rein (**75**) finds that the number of points per unit of area greatly varies. He finds them most dense on the side of the finger, where they average 2 per sq. cm., and sparsest on the upper arm, where they average only .2 per sq. cm. He studies the grouping of the warmth points in connection with the course of the sensory nerves, and finds a marked tendency for them to follow the nerve trunks and branches. Between these regions there lie more or less distinct areas of complete or partial anesthesia to warmth. This author also makes a study of the warmth sensitivity of the tongue (**76**). He finds that on the tongue surface only the fungiform papillae are sensitive to warmth. The papillae at the tip of the tongue are found to be more often sensitive and to have lower thresholds than those at the side, and these in turn are found to be more sensitive than those at the back. The threshold everywhere on the tongue is found to be much higher than that on the outer skin. Strughold (**96**) investigates the cold sensitivity of the whole mouth cavity, and finds it low as compared with that of the surface of the outer skin. The distribution of the cold sense on the tongue is found to correspond only partly to that found for warmth by Rein, indicating a difference in receptors. Strughold, in this and several other studies, is especially interested in determining what structures mediate cold. He finds considerable evidence that the end-bulbs of Krause perform this function. In all parts of the mouth cavity which he has found sensitive to cold these end-bulbs have been shown to exist, though it has not been shown that they are lacking in parts insensitive to cold. The other studies of this series have to do with the cold sensitivity of the eye. In two studies carried out with Karbe (**92, 94**) cold sensitivity is mapped for the cornea and sclerotic, and for some of the structures adjacent to the eyeball. Von Frey's earlier results for the cornea and sclerotic are confirmed. It is found that these regions respond with only two sensory qualities, pain and cold. The average density of the cold points is found to be 14 per sq. cm. Comparing their own results for cold sensitivity with histological findings for this region, the authors find support for the view that the end-bulbs of Krause are the receptors for cold. This is further borne out by Strughold's study (**93**) of the cold thresholds for different parts of the eye. He

finds a correspondence between the magnitude of the threshold and the depths at which histologists have found the end-bulbs of Krause to lie. Working with Karbe (**95**), and using a recently developed method of staining the living eye with methylene blue to make the nervous structures visible, Strughold locates end-bulbs of Krause in the sclerotic. As long as the stain lasted the end-bulbs were insensitive, so it was necessary to make sketches in order to locate and stimulate them later after the return of sensitivity. When this was done the points were found to respond to cold, though the surrounding region did not. Rein (**72**) finds it quite impossible to arouse a paradoxical sensation of warmth even under what he regards as the most favorable conditions for its appearance. He also finds evidence for the existence of a new cutaneous sensory quality which he designates as warmth pain.

A series of experimental studies on temperature has also appeared from Goldscheider's laboratory. Goldscheider and Ehrmann (**27**) find that carbon dioxide and oxygen each have the effect of arousing the warmth receptors of the skin of the hand, even at a temperature far below skin temperature. The effect of carbon dioxide is much more marked than that of oxygen. Control experiments with air sometimes gave cold, but never warmth. Experimenting with other chemical substances, Goldscheider and Hahn (**28**) find that the ones which affect the pressure receptors also affect those for temperature, often to a greater degree, some substances showing an affinity for cold and others for warmth. Their results tell against the idea of a stratification of the end-organs of temperature, and indicate that the endings for both senses lie at the boundary between epidermis and cutis. These investigators, in contrast to Rein, find it possible to arouse paradoxical sensations of warmth. Somewhat similar results are obtained by Goldscheider and Joachimoglu (**29**) with three chloride derivatives. With Hahn, Goldscheider (**30**) tests Ebbecke's temperature theory, repeating the latter's experiment and making a number of others. Ebbecke's theory makes the essential thing for the appearance of warmth or cold a temperature difference within the skin layers next to the end-organs of the temperature nerves. Goldscheider and Hahn believe all the phenomena observed can be explained in other ways. Sherrington, however, finds (**81**) support for Ebbecke's theory in certain reactions of spinal dogs subjected to various conditions of temperature stimulation. In another paper Goldscheider and Hahn (**31**) take up anew the question why a cooled object seems heavier than one of indifferent temperature. They con-

clude that the apparent additional weight is due to the arousal of the cold nerves, and not, as has sometimes been assumed, to the arousal of cold pain. Warmth, they find, has a similar though lesser effect. These authors also find (32) that the vasomotor processes are not experienced as such, but that they may give rise to temperature sensations or even to sensations of strain. In this connection Uhlenbruck's work is of interest. This investigator (99) studies the reaction of the capillaries when cutaneous sensations are aroused. He finds that all skin sensations are accompanied by a contraction of the vessels, the reaction varying in duration and strength with the duration and intensity of the sensation.

Pütter's work (70) is a continuation of his earlier experiments on the difference thresholds for temperature upon the ball of the thumb. Six new areas are investigated, three on parts of the body which are normally uncovered, three on parts usually covered by clothing. The difference threshold is found to vary somewhat between these parts. The finest difference sensitivity occurs at 30°-35°. In general the earlier results are confirmed, especially in their lack of conformity to Weber's Law. Myers (62) sketches a theory of sensory adaptation, illustrating it by the temperature sense. The theory rests upon an analogy with inhibition of antagonistic muscles. The development of warmth is supposed to inhibit the opposite mechanism which, when aroused, gives cold; and just as flexion and extension may balance each other in muscular posture, so opposite sensory mechanisms may balance each other, and no sensation arises.

Achelis (1), after a careful analysis and classification of various forms of pain, develops a phylogenetic theory to account for it. He lays especial emphasis upon its motor or "drive" character. This, he thinks, is a relic of its original character as an animal response. In the course of development the original movements became less and less prominent, and came to resemble more the expressive movements of feeling. Then, with the further dropping out of motor, and even of visceral processes, pain came to be more like a sensation. It has not, however, even yet achieved quite the status of a sensation, because it is not attributed in experience to its object as is red or cold. Thus, in his view, pain is a process holding a position midway between feeling and sensation.

Strughold (91), working on forty-two different skin areas, studies the density of the pain points and their thresholds. On the hairy areas he finds that they average about 175 per sq. cm., on other surfaces about 54 per sq. cm. He estimates the total number of pain

points on the human body as about three and a half million. Variations in density on hairy surfaces are in general small, and regional differences in sensitivity are much greater than those of density. Schriever (78) studies the pain sensitivity of the mouth cavity. He presents his topographical results in maps of the regions studied. The pain thresholds of the mucous of the mouth are found to be significantly higher than those of the outer skin. A result with important theoretical bearings is the confirmation of the analgesic condition of Kiesow's cheek area. Schriever finds it sensitive to pressure but insensitive to pain stimuli. Hahn and Hajen (38) also study this area and get different results. They find it to be as sensitive to pain as the skin of the outer surface of the body. As stimulus they use a needle fastened to a glass tube and applied by hand. Schriever criticizes them for this technique because of the lack of an exact control over the force with which the stimulus is applied, and he suggests that they find the area sensitive to pain because the needle penetrates to deeper lying structures.

Kant and Hahn (47) study the sensitivity of the surface of the eye. This is, of course, another region which has figured prominently in theoretical discussions of the nature of pain. As noted above, v. Frey and his pupils have found only two forms of sensitivity in this area, pain and cold. Whatever the stimulus, these are the only forms of sensation aroused. Kant and Hahn use as stimulus a bit of fine thread 3 cm. long. When this is applied like a touch-hair it bends at 10 mg. Goldscheider himself took part in some of the experiments. The authors find that in about half the applications of the thread to the cornea and sclerotic pure pressure sensations are aroused. Pure pain seldom appeared, and the nature of the aroused sensation, pressure or pain, depended upon the pressure with which the thread was applied. Pain was most prominent in the center of the cornea, shading off toward the edges, and disappearing on the sclerotic. When the eye was cocainized the threshold for pain was always raised to a greater degree than that for pressure. It was not possible to establish any significant difference between the touch and pressure sensations aroused here and those aroused on other parts of the body. Another study, by Hoefer and Kohlrausch (44), approaches the same general question from a different angle. Using an induction current just strong enough barely to cross the threshold, these authors try the effect of stimulating isolated pain and pressure points. They succeed in getting pure pressure sensations from pain points. Hoefer (43) points out that v. Frey's assumption of specific

nerves for pain will hold only if the pain experiences are true sensations. He holds that descriptions of them by both v. Frey and Goldscheider indicate that they are more complicated. As for points specifically sensitive to pain alone, he holds that they do not exist, for each point seems to mediate various sensations. Experimental support for the latter contention is found in the experiment with Kohlrausch just described. Goldscheider himself (**25**) makes reference to this work of Hoefer and Kohlrausch in a critical analysis of recent work bearing on the question of specific nerves for pain. He concludes that the existence of such receptors has not been established. Shawe (**80**) studies the effect of a faradic current applied to the median nerve upon the pressure-pain sensibility of the palm of the hand. He finds that currents of weak or of medium strength increase sensitivity, but that strong currents reduce it. He finds the same changes on the palm of the hand on the side opposite to that on which the median nerve is stimulated. He concludes that the change in sensitivity is due chiefly to changes in the nerve cells with which the afferent nerves are connected.

Two other rather general treatments of the subject of pain have appeared. Piéron (**69**) rejects the idea of pain as an elementary sensation as being too simple to account for the facts of introspective observation. He also rejects the idea of pain as an affective quality attaching to sensation, because this would involve supplementary nervous processes of a highly conjectural nature. He would himself distinguish two kinds of pain sensation, prick (piqûre) and burn (brûlure). These he accounts for neurologically by relating burn, the coarser, more vivid form of pain, to thalamic reactions, and prick, the finer form, to cortical reactions. Strümpell's discussion (**97**) treats pain largely from a clinical point of view. The function of pain is to serve as a warning when any of the bodily processes are threatened. Phylogenetically pain, next to the elementary touch sensation, is probably the oldest sense quality. Cutaneous pain is regarded as a function of the sympathetic system.

Several papers have appeared which deal in various ways with the functional relationships of different cutaneous sense elements. Most of the writers relate their findings or views in one way or another to the Head theory. Trotter (**98**), who carried out with Davies the first re-trial of Head's experiment, makes a critical survey of the theory. Among other things he points out that Head assumes that the phenomena which begin to appear as soon as the nerve fibers begin to regenerate are normal phenomena, whereas when one con-

siders the condition of the nerve trunk it is more likely that they are pathological. He points out that throughout the nervous system the fibers are, for the most part, protected by insulation from other bodily structures. Where this is not the case, as for example in the free nerve endings of the skin, stimulation of the fibers is apt to produce sensations of unusual vigor and intensity. Thus when intensification occurs, as it so prominently does in areas supplied by regenerating nerves, it may be due to the temporarily unprotected and injured state of the nerve fibers. This brief and partial summary by no means does justice to a very suggestive and important discussion. Stopford (**87, 88, 89**) points out that the nerves which were cut in Head's arm were chosen because it was supposed that their fibers were distributed to the skin alone. His own investigations have convinced him that these nerves—indeed any nerves that are important enough functionally to be of interest in this connection—carry fibers which go to the deeper structures as well as those which go to the skin. He experiments on deep sensibility, and is convinced that it is of two kinds, just as Head found two kinds of superficial sensitivity. He thinks of one of these as related to the thalamus, the other as related to the cortex; and he advocates an explanation of the different stages of recovery, not only here but in the case of superficial sensitivity as well, on a central, functional, instead of on a peripheral, structural basis. A. Gordon (**35**) reports a case in which the ulnar nerve is affected, and in which all deep sensibility is lost, as well as all superficial sensibility. Waterston (**100**) advances the view that the epithelium of the skin is the receptor for touch and temperature. At any given time sensitivity shows a punctate distribution which, however, is always changing. This is explained by the view that in the skin there is a constant coming and going of activity of the different parts. Under certain conditions every point on the skin may be sensitive to stimulation, *e.g.*, in erythema every point is found sensitive to heat. Byrne (**7**) brings forward clinical evidence for his views on cutaneous sensibility. He distinguishes two systems, critical and affective, which are supposed to function antagonistically. The critical system is subdivided into systems of fibers for warmth, cold, etc., but the affective system does not become differentiated except as it functions side by side with the critical system. Neither system seems to be prior to the other in point of time or development. In deep sensibility the same division into critical and affective systems is supposed to exist. Von Weizsäcker (**104**) studies the phenomenon of intensification, using normal and pathological subjects. He con-

cludes that the phenomenon exists wherever there is any sensibility at all. In another article (103) the author makes a general survey of the skin senses, and tries to clear the ground for future investigation.

Before closing the account of cutaneous sensation mention should be made of several studies of various kinds which are of interest in this field, though not immediately related to those already considered. Kadanoff (46) finds in the sole of the foot of man a form of nerve ending not hitherto described. He regards it as a transitional form between the arborized nerve endings of the *stratum reticulare* and the touch cells of Merkel. Basler (5) makes a study of the mechanical characteristics of the hair of the human head which should be of value in cutaneous work. Peiper (68) studies some prematurely born infants, and finds that they respond to pain and to cold stimuli just as normal newborn children do. Gault (24) reports further progress in his experiments on tactual interpretation of oral speech. Strughold (90) studies the effect upon the skin and its sensitivity of two of the most powerful of the poison gases used in the war. In varying degrees they raise the thresholds for pressure, warmth, and especially cold. The pain threshold remains normal until itching or burning sets in, when it is somewhat lowered. This lowered pain threshold may persist for two or three weeks. Because of disagreements between investigators, v. Frey (20) takes up again the question of receptors for erotic sensations. He tests different parts of the penis with faradic and mechanical stimuli. He finds that as long as the effects of the stimuli are confined to the skin no erotic sensations result, though the usual cutaneous qualities may be aroused. He concludes that erotic sensations do not result from the stimulation of any superficial receptors. Two studies of after-sensations have appeared, in each of which the investigator worked with both normal and pathological subjects. Stein (84) is especially concerned with the relationship of after-sensations to adaptation, Günther (37) with their tendency to recur rhythmically. Von Weizsäcker (102) points out the value of exact quantitative methods of testing sensibility in pathological cases. He suggests that since the use of quantitative methods has revealed things which could not have been discovered by ordinary clinical tests, some of the uncertainty about ataxia may be due to lack of sufficiently developed methods.

In a series of studies Lippay investigates the process of lifting a weight when both arms are used in the lifting. The apparatus consists of a rod with a hand-grip at each end. The weight is hung from the middle, but can be shifted from side to side, thus distributing

the downward pull unevenly to the two hands. For comparison, a short rod with a single hand-grip is used in one-armed lifting. When comparisons of this sort are made, the normal weight used for two-armed lifting is twice as heavy as that used for one-armed. Lippay finds (**55**) that the difference sensitivity is significantly greater for two-armed than for one-armed lifting. He explains this on the ground that a larger number of sensitive elements are brought into action in two-armed lifting. With the weight unevenly distributed (**56**) accurate comparison was still possible. If the weight was evenly distributed at the first lift, and unevenly at the second, there was a tendency to overestimate the second weight. In Lippay's third contribution (**57**) the subjects' ability to compare the magnitude of a weight increase with that of a weight decrease is tested and found fairly well developed. Finally, this author experiments (**58**) on contrast in this sense field, making quantitative determinations of its degree.

Allers and Saito (**2**) test the difference sensitivity for lifted weights with the lifting muscles in varying states of fatigue. A single vigorous contraction (as in trying to lift a weight too heavy to raise) results in an increase of sensitivity, but with continued work and consequent fatigue the sensitivity decreases. The condition of the musculature is regarded by the authors as the essential basis of the judgment of weight. Panzel and v. Weizsäcker (**65, 66**), on the basis of a study carried out by the former under the latter's direction, conclude that it is not possible to isolate an organically separate strength sense. Their experiments on normal subjects involved the holding rather than the raising of the weights, with the limb in question held in different positions. They call special attention to the importance for the estimation of weight of the position of the limb with reference to gravity, and the position of the joints involved. Pathological cases showed various disturbances of the ability to judge weights, sometimes amounting to anesthesia of the strength sense, but here too the authors point to various conditions not directly concerned with the strength sense, as such, which have a determining effect upon estimation. Goldstein (**34**) studies the effect upon the kinesthetic sense of changes in muscular tonus due to pathological cerebellar conditions.

Reid (**71**) carries out an experiment on lifted weights in which the subjects are given three different instructions at different times. These were designed to focus attention in lifting (a) upon the weights themselves, (b) upon pressure sensations in the finger tips,

or (c) upon kinesthetic sensations in the wrist. No single subject was able to follow all the instructions. The instruction which required the subjects to judge the weights themselves gave the most accurate results. The pressure pattern in the fingers came next, and the kinesthetic pattern in the wrist gave the least accurate results. Rudisill (77) repeats Reid's experiment, requiring more frequent introspective reports from the subjects. Here again the stimulus attitude gave the most accurate results. The author finds that the instructions used in the experiment may be carried out by a trained observer, but the results are of questionable value without an introspective check on every judgment. Garrison's work (23) was planned as a companion study to Reid's. Münsterberg's arm-movement apparatus was used, and the subjects worked under two different instructions: (a) to take the movements as linear distances in space; (b) to discriminate the pressure patterns which the movements set up in the elbow. It is found here, as in the experiments just described, that change in instruction does not necessarily bring about a change in attitude. K. Gordon's experiment on lifted weights (36) is devised to answer the question as to whether the judgment of a group of persons is any better than the judgment of the average member of the group. It is found that the larger the number of subjects whose judgments are averaged the better the resulting judgment. The results for the group as a whole are, under the conditions of the experiment, equal to those of its best members.

Arndts (3, 4) experiments on the perception of position, using a chair so constructed that the surfaces with which the subject's skin comes in contact can be made cold, thus anesthetizing the superficial receptors. With the skin rendered anesthetic, perception of position of the bodily members is found unimpaired, and the author concludes that this ability depends upon deep sensibility. For finer discriminations of position he thinks the coöperation of the skin senses would be necessary. In the grosser discrimination studied the author thinks that muscle sensations played the most important part. Similar results and conclusions are arrived at by Kleinknecht and Lueg (50).

Mangold (60, 61) describes an apparatus for measuring the hardness of a muscle in different states of contraction. It has already been used in a study of kinesthesia by Hueck (45). This investigator uses the apparatus to measure the accuracy with which a subject can reproduce a given degree of muscular contraction, gauging it by the sensations of muscular strain. He finds that the subjects can do this with considerable accuracy, especially those who have been

trained by work or sport to an accurate use of their larger muscles. When it was a case of doubling or of halving the original contraction, the results were less accurate, but were better for doubling than for halving.

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COLOR DEFECTS: MEASUREMENT, CLASSIFICATION, HEREDITY

BY SAMUEL P. HAYES
Mount Holyoke College

A large number of articles have appeared since the last review in BULLETIN for 1919, many of which had been printed before that date but were inaccessible because of restrictions during and after the war.

Several writers give descriptions of well known methods of testing color defects. Jennings (**65**) presents for the guidance of the practical examiner careful directions for giving and scoring a number of tests—the Holmgren Wool Test, the Jennings Self-Recording Color Test, the Williams Lantern Test, the Stilling Plates, the Nagel Card Test and the Nagel Anomaloscope.[1] Titchener (**105**) advises the use of the Oldberg worsteds authorized by Holmgren as these are more nearly uniform from set to set than many of the collections of wool supplied by other firms. Collins (**12**) gives explicit directions for giving the Holmgren, Nagel and Stilling tests and the Edridge-Green Lantern Test, and describes various color-naming tests, the use of color equations, contrast effects and negative afterimages, the Roaf Painting Test, and a test of color preference by the method of paired comparison. Miss Collins reports the detailed results obtained through the use of her long series of tests with ten color-blind subjects and criticises the tests in the light of their use. Her book will be a great boon to students just entering the maze of color-sense testing. Cowdrick and Winfield (**14**) give explicit directions for the use of the Hering Color Blind Apparatus, in lieu of the directions supposed to have been prepared by Hering, but not obtainable.

Some extensive surveys of color efficiency have appeared. Franke (**32**) reports the result of a comparative study in which 750

[1] For the convenience of students of color-vision, practically all the tests mentioned in this review have been listed among the references, with the names of publishers or supply houses and approximate present prices.

subjects were examined with the Nagel Cards, the Stilling Plates, Cohn's Contrast Card and the Nagel Anomaloscope. He finds discordant results with the different tests in 167 cases. On the whole he considers the Nagel Cards and the Stilling Plates most reliable and practical, but advises the use of the Anomaloscope in all doubtful cases. Vierling (**110**) cites extensive statistics to show that if one supplements the Nagel with the Stilling and Cohn tests, very satisfactory results may be obtained. Taylor (**100**) reports the results of 1,000 consecutive tests in the railroad service of New South Wales, using the Holmgren and Stilling tests with the Williams Lantern. The Holmgren and Williams tests are official, but he always uses the Stilling when in doubt, and does not trust the Holmgren when it gives results contradictory to the others. He concludes that any man who passes the lantern test without mistakes and is normal with the Stilling Plates will make a safe engineer. Verrey (**108**) reports the discovery of nearly 6 per cent of color defectives among locomotive engineers who three years before had passed the Holmgren, Nagel and Cohn tests. He used the Stilling Plates first, and then checked up all doubtful cases with the Nagel Anomaloscope. He and Wölfflin (**109**) find that the Anomaloscope gives such delicate measurements that we may soon be able to speak of color defects in quantitative terms such as are now used in reports of visual acuity. He recommends that the Swiss Ophthalmological Society establish normal limits for the equation and pass all candidates who test within these limits. Sulina (**99**) tested 336 children from 1 to 14 years of age, using brightly painted toys with the little children and card tests, wool tests and the Chibret apparatus with the older children. He concludes that the color sense is not developed under two years (15 cases), but that it begins to function and can be demonstrated at two years (29 cases), becoming completely developed between the fourth and the sixth year (53 cases). He found no cases of color blindness among the children over six years in age (239 cases), but reports a slight weakness for green in about 16 per cent of the Russian children and in 18 per cent of the Jewish children. Further reports of surveys are mentioned in the discussion of the heredity of color blindness later in this review.

Critical discussions of the customary methods of testing color vision are numerous. Grow (**39**) finds the Nagel and Stilling tests too difficult for the average examiner to manage and thinks both can be passed by subjects who take the trouble to practice with them. Although he recognizes various deficiencies in the Holmgren test,

he claims that it has been used for 40 years in the U. S. Navy without the occurrence of any serious accident which could be traced to defective color vision. He finds various difficulties with the Jennings test: the examiner may easily make a mistake in putting in the record sheets; bright subjects may memorize it; many normal subjects make mistakes; it does not detect the short-spectrum defectives. He says he has devised a test of his own which cannot be mastered by previous study, but he has not yet published his results. Hunt (**63**), thinking that the Jennings test involved a type of comprehension often required in certain performance tests of intelligence, made an extended study of recruits and school boys, and correlated the time required in performing the Jennings test with the test scores obtained with the Stearns Group Intelligence Test used with the U. S. Reserve Forces. He found very little relation between the two. Some of the intellectually superior took nearly 4 minutes to complete the Jennings test while some of the feebleminded subjects finished in less than half a minute, "these not being inhibited in the mechanical performance by cerebration. To them green was green and all they had to do was to find green; with those of superior intelligence it was necessary to determine whether there was more green than brown in the olive drab." Boström (**5**) reports a renewed interest in Sweden through the discovery of a deuteranomalous engineer. He criticises the Holmgren test, the lantern tests and the Nagel Cards, giving his vote for the Stilling Plates and the Nagel Anomaloscope. He recommends that Sweden establish a department for the investigation of doubtful cases. Collins (**12**) concludes that objective tests, in which the subject does something which may be measured, are much more satisfactory than subjective tests, which depend upon the testimony of the subject concerning his mental experiences of color. Hence she values her contrast and after-image tests mainly for the supplementary evidence they give. As objective tests of great value she cites the Holmgren Wool Test with certain modifications of procedure, her Bradley Paper Test, the Stilling Plates and Part A of the Nagel Card Test. The Edridge-Green Lantern, she thinks, is of the highest practical value. "It has been devised after a long period spent in practical work with color-blinds, and is based on a thorough knowledge of their characteristics. It combines the recognition of colors with the naming of them, which was found to be of great utility throughout the experiments. The modifying glasses are well adapted for the purposes intended, and proved most satisfactory. The test has the

advantage that a short examination with it is sufficient to reveal the defect. Further, it seems impossible to coach a color-blind to pass such a test, so many combinations of colors are possible."

A heated debate has been going on in the German periodicals over the relative values of various well known tests and many new methods for office or clinic use have been described. Oloff (84, 85) tells how the Holmgren and Stilling tests were supplanted by the Nagel Cards and Anomaloscope, which became official and supreme in Germany in 1905. Before the war, however, many criticisms had been published, and when Hess (49) showed that a serious wreck in 1918, involving considerable loss of life, could be traced to the color deficiency of an engineer who had repeatedly passed the Holmgren, Stilling and Nagel tests, the necessity for an improvement in methods was generally conceded. Hess claims that reliable results can never be obtained with the customary methods of office testing, since it is impossible to keep the test conditions constant: colored plates vary in tone and fade with exposure to light; worsteds become soiled; examinations are made under varying conditions of illumination—with blue sky or clouds, in the morning or the afternoon, with reflections from surrounding buildings, from grass, snow, etc. To meet the difficulty, Hess proposes to substitute variable for permanent test colors and to make exact measurements of color deficiency in terms of normal attainment under like conditions. He criticises (58) the use of the Nagel Anomaloscope because it demonstrates only "red-green inequality" and gives no information about the much more important cases in which sensitivity to both red and green is reduced equally. Other writers propose various modifications and improvements of present methods. Just as the Holmgren Wool Test has appeared in various forms intended to be improvements (Cohn, Donders, Magnus, Daae, Oliver, Thompson, Jennings) so now the Stilling test is being revised. The test itself has appeared in a 16th edition under the direction of Hertel (98). Edridge-Green (23) presents a set of 24 cards, 5½ by 6 inches in size, upon which are printed splotches of color in different shades and tints. These splotches all have the same shape and are arranged in the same order on all the cards. The colors chosen are those which defectives of one or other of Edridge-Green's classes ordinarily confuse. The splotches of one color are arranged to form a letter, the splotches of the other color constituting a background. Burch (6) describes a modification of the Stilling test which provides for the substitution of new plates at will. A series of cards, upon which

letters have been painted in confusion colors, is placed in a box and viewed through numerous holes in a screen. By means of a lens the colored letters are put slightly out of focus to obliterate the brush-marks. Ishihara (**64**) offers a convenient booklet of plates formed on the same plan. Each plate is filled with colored circles of different sizes; part of the circles form a letter while the rest form a background in a confusion color. There are 16 plates in all. Great ingenuity has been used in forming them. Plate 1 can be read equally well by normal and defective; in plates 2, 3 and 4, the normal subject sees one numeral, a dichromate another and a totally color-blind subject would not see either numeral; plate 5 is similar, but includes 4 numerals; in plates 6, 7, 8 and 9 normal subjects find a numeral easily, while defectives have great difficulty; in plates 10 and 11, on the other hand, dichromates read easily certain numerals which are difficult for the normal and the totally color-blind; in plates 12 and 13 protanopes read one numeral and deuteranopes another, while normal subjects and incomplete dichromates read both; in plates 14, 15 and 16 lines are substituted for numerals, in order to test illiterates. Clark (**8**) reports the results of a comparative study of the Edridge-Green, Stilling and Ishihara tests. Wölfflin (**122**) describes a modification of the Stilling test along another line. Starting from the claim made by Hess that certain persons are supersensitive to one or another color, he attempts to revise the Stilling Tables by the use of "Umschlagfarben"—colors produced by chemical mixture in such a way that to the normal person they look alike in daylight but are clearly distinguishable in ordinary artificial light, while to the supersensitive they will be distinguishable by daylight, since some colors would appear reddish and others greenish to the supersensitive. Such a test when perfected would diagnose supernormal sensitiveness to one or two colors, and accomplish this much more quickly than is now possible with the color wheel, or the spectroscope.

Podesta (**88**) seeks to avoid the necessity for a multitude of tests by a combination of the best features of the Stilling, Nagel and Cohn tests. He claims three advantages over his predecessors: the plates are large (29 x 39 cm.) and bound so they can be used as wall charts, and for group demonstration; a much greater variety of colors has been used, there being three colored tables on each of the eight large plates; Roman letters have been substituted for the Nagel dots and the Stilling digits. These letters are arranged in such a way that one or more words are visible against a back-

ground of another color. In most of the tables, two words are printed in different colors. Since one word appears in a confusion color, it would be invisible to a color-blind. The other word printed in a darker tone but the same color as the background would appear relatively inconspicuous to the normal subject, but quite prominent to the color-blind who from their childhood have been accustomed to distinguishing colors by differences in brightness. Oloff (86) says, "Podesta's combination and opposition of colors and brightnesses in the same word-picture is a very clever idea. Moreover, those with color defect do not feel so helpless with this as with a test like Stilling's. There is always some word they can read, though it may not be the same one that a normal person would pick out." Oloff has used the Podesta test for years and recommends its use by physicians. Charles (7) commends the Adler Pencil Test because it gives the examiner a definite record of the subject's color confusions. The test material consists of 98 colored pencils. The subject is allowed to experiment with the pencils and then is asked to match the marks he has made with marks made by the examiner who uses standard red, green, blue and yellow pencils. Seydel (97) commends the Helmbold color matching test, after using it with 100 subjects. This apparatus consists of two movable discs 18 cm. in diameter, mounted side by side, each containing a circle of colored dots 6 mm. in diameter around the edge of the disc. The dots are cut from papers of 58 confusion colors selected by reference to the work of Stilling, Nagel, Holmgren, Daae and the author. Over the discs is placed a shield with two holes at the center through which one dot from each disc can be seen at a time. By turning the discs around, any dot may be compared with any other, and the equation recorded by the use of minute numbers printed beside the dots, but visible only when the shield is lifted away. Roaf (91) describes a painting test by means of which he hopes to determine which part of a subject's spectrum is defective. Model paintings consisting of squares divided geometrically into 25 parts each differently colored are laid before the subject, who is requested to duplicate the model by selecting colors from a special box containing 15 pigments. When the subject has finished, the model painting is examined through colored screens which cut out various parts of the spectrum, until a minimum combination of screens is obtained which makes the original look like the subject's copy. A study of the screens used will then reveal the part of the spectrum to which the subject is insensitive. Holth (61) describes a number of simple tests for the discovery of

acquired color defects,—a black wooden cylinder with 3 discs on a side, spaced 3½ cm. apart, and a dark grey cardboard with similar sets of discs, to be used for central scotoma, and a set of cubes of different sizes carrying colored discs, for measuring the color zones. In all his tests he uses the Engelking and Eckstein (29) papers which do not change in color tone when seen on different parts of the periphery.

A few tests are now available for use with groups of subjects, and psychologists wishing to make surveys of large classes in order to discover subjects for intensive laboratory work in color deficiency will doubtless be glad to take advantage of them. Many of the Podesta charts can be read as well at 25 feet as at 3, by a normal observer, and if several copies were shown by assistants in different parts of a large lecture room, a good-sized class could be tested quite speedily. Westcott (116) has worked out a group test through the use of a colored lantern slide, following the general plan of the Holmgren test. The slide contains three test colors, green, rose and blue, and 40 numbered samples of color selected with the assistance of a spectroscope. Of these 10 are green, 5 rose, 5 red and the remainder confusion colors in blues, browns and greys. In giving the test, the colors are projected upon a screen and the class is asked to make a list, by number, of all the colors which resemble color A (Green). These lists are signed and collected and the test is repeated for B (Rose) and later for C (Red). Hess (48) reports that if small red and green discs are combined on a color wheel to match large discs of yellowish grey and shown to a large group, some will see the inner circle as reddish and some as greenish. By asking for a written report, anomalous cases may be located.

Two writers think that color-blindness shows itself in the face. Taylor (101) reaffirms his belief that color defect is often indicated by changes in the face, voice and general behavior, and suggests that this knowledge may be an aid in detecting cases. He claims that the tone-deaf react in a similar fashion, and assumes a close association between color sense, musical sense and moral sense. He believes that color-blindness and tone-deafness are both degenerative conditions. Wirth (118) finds the color-blind very likely to show a hectic redness of the cheeks. He has noted this characteristic in many of his cases and quotes Kirschmann as holding a similar view. In the 34 cases studied he finds a correlation of .66 between color-blindness and abnormal facial coloring, and raises the question

whether both traits may not be symptoms of general constitutional weakness.

Of conspicuous importance, especially in the laboratory study of doubtful cases, are the new methods described and demonstrated by Hess in a series of articles, culminating in an extended review (58) of the work on color vision during the last 20 years, in which 194 articles are considered. Since we cannot depend upon the results obtained by the use of pigments, Hess (49) undertakes to invent types of apparatus which will permit the continuous variation of the color and brightness of the stimulus, without the use of costly spectral apparatus or time-consuming tests with rotating discs. He has perfected three types of "Farbensinnprüfer," in all of which color mixtures are obtained through the use of the Goldberg wedge-shaped color filters. His "Modell für die Praxis," he says, meets all the demands made of a practical color test—that it should give a sure diagnosis, make possible the examination of large numbers of subjects without loss of time, be cheap, and not be too difficult for subject or examiner. The subject is asked to look at a transparent spot of oil paper, 1 cm. in diameter, at the center of a dull white card. The spot is illuminated by an electric light inside the apparatus, which sends its rays through color filters. To test for inequalities in sensitivity for red and green, blue and yellow filters are combined to produce green, and a mixture of red and grey is reflected upon the green by means of a movable mirror. By changing the proportions of the different colors, the spot may be made colorless to the normal eye, and by moving the apparatus toward or away from the source of external light, the ground may be equated with the spot in brightness. The subject is then asked what color he sees, and classed as deuteranomalous if he calls the spot red, protanomalous if he calls it green. This test may be confirmed by changing the relations of the color filters till the spot appears colorless to the subject and recording its appearance to the normal subject. To test for color-blindness, the red light is turned off and the blue and yellow wedges moved so as to produce a series of colors from yellow-green through green to blue-green, equating spot and background in brightness by moving the apparatus as before. The subject is asked to name the colors, and his statements recorded with those of a normal subject observing the spot at the same time. Generally dichromates call the yellowish-green yellow, and the bluish-green blue. Hess cites as additional advantages, the facts that tests may be made either in natural or in artificial light and that

subject and examiner can both see the changes in color and brightness at the same time, instead of being obliged to look successively into a tube. Hess has a somewhat more elaborate "Klinisches Modell" which uses reflected light in much the same way as in the Hering Color Testing Apparatus. This model may also be used to chart the color zones of the eye and to determine the color thresholds. His "Tunnel Modell" yields exact measurements, in terms of the distance one must move the light which illuminates the red filter. Hess claims the following advantages over the Nagel Anomaloscope: exact equations are obtainable; only the red is changed while in the anomaloscope both red and green are changed; only the intensity of the red is changed while in the anomaloscope the vibration rates of both red and green are changed; not merely the fact, but also the degree of color defect is determined; the apparatus is easily and quickly handled. The use of color filters for the exact measurement of color defect is recommended also by Ferree and Rand (**33**), Rochat (**93**) and Hegner (**42**).

In a later article Hess (**55**) describes an apparatus which attains much the same results as his first two models, but with the use of color discs in place of color filters. His discs are cut on a curve from center to periphery so that for each mm. on the radius there is one more degree of curvature. In front of the color wheel he mounts a grey screen with a hole in the center, and in front of this a still larger screen pierced by a tube. The screens and tube are movable right and left, so that a position may be found in which the mixture seen through the tube and the screen matches the screen in color, and this screen can be rotated on a vertical axis so that it will reflect just enough light to match in brightness the mixture on the color wheel.

The "Differential-Pupilloskop" makes possible still further measurements which Hess (**50**) considers extremely important in the diagnosis of acquired as well as of congenital color defects. From his extensive studies of the color vision of man and animals, Hess drew the conclusion that in the eye our sensory and motor receptors are identical. In the middle of the retina stimulations which are sensed as colors are accompanied by the ability to change the size of the pupil, and this ability decreases from center to periphery. If two lights of unequal intensity play upon the eye in rapid succession the pupils become narrower with the strong and wider with the weak light. With two lights of different color but equal brightness, the pupils remain unchanged. In total color-

blindness these pupillary changes do not occur, and in partial color defects a loss of color sensitivity is accompanied by a loss of pupillary change for the color chiefly involved, while there may be a greater response to other colors. Protanopes and protanomalous trichromates show a lower motor value for red and a higher than normal value for blue; deuteranopes show about normal values for red and blue; deuteranomalous trichromates often show a supernormal motor response for red. Engelking (**30**) and Groethuysen (**38**) report favorably upon the use of the Pupilloskop, Groethuysen having made thousands of measurements with it.

Several important studies of color defectives have been published. Collins (**12**) reports in detail the careful examination of ten dichromates by a long series of tests. The primary object of her investigation was a critical study of the value of various methods of testing color vision, but the psychological question of the sensations experienced by color defectives soon became the central interest. Her work is peculiarly uninfluenced by questions of theory. Her main conclusions may be briefly summarized. (1) Dichromates vary enormously in their sensitivity to red and green. (2) Besides the well known neutral zone in the blue-green region, dichromates have a second neutral zone in the extraspectral purple which for us is complementary to green. (3) Dichromates are especially sensitive to contrast effects and show very rapid color fatigue. (4) A modification in the intensity of light is for dichromates equivalent to a change in color. (5) Dichromates do not guess at colors, as has often been supposed, but try to use our color names for a fairly constant color system different from ours, even such apparently meaningless terms as "reddish-green" and "greenish-red" being used with such consistency that they seem to describe a true color experience. (6) Color-blindness is so common and makes such an important vocational handicap when present that it seems wise to institute a systematic examination of all children before they leave school. Reichert (**89**), whose right eye is considered deuteranopic while his left is normal, reports the results of naming spectral colors and making equations with rotating discs, using the eyes separately. He seems to have a typical full-length dichromatic spectrum with a neutral zone in the blue-green region. Roenne (**94**) reports a study of incompletely color-blind persons with equations on rotating discs in which green plus black were made to match green plus red plus blue-violet. Determining in each case the size of the purple sector which his subjects could not distinguish, he concludes

that Köllner is right in claiming that dichromates and anomalous trichromates are linked through transition forms and suggests that dichromates may be considered as "reduction forms" from the anomalous rather than from the normal, as Von Kries suggested. Köllner (71) describes an extended study of the Rayleigh equations of anomalous trichromates which he undertook to determine whether they may be regarded as transition forms between the normal and the color-blind. He concludes that the Rayleigh equation of this group can be explained only by assuming a change in the color value of red and green light. The deuteranope sees both red and green as shades of yellow. The deuteranomalous trichromate has not lost quite so much and the green has suffered more than the red. The protanomalous trichromate also shows more uncertainty with green than with red, but is chiefly distinguished from the deuteranomalous by the greatly reduced brightness values of colors. The deuteranomalous equation may be changed into the protanomalous by the use of absorption glasses which reduce the brightness of the red and yellow lights.

The question of heightened contrast among anomalous cases has had considerable attention. It will be remembered that Guttmann made much of this in his early reports of experiments upon his own color vision, and he still assumes the fact in a recent article (40) in which he attempts to prove that the heightened contrast of the anomalous is due to retinal rather than central factors. His method consists in presenting patterns calculated to produce contrast colors to a single eye in the ordinary way, and to the two eyes by means of a stereoscope so arranged that the inducing color and the grey field on which a contrast color might appear are presented to different eyes. By the monocular method he finds the usual heightened contrast, but with the binocular method his anomalous trichromates experience less contrast than normal subjects. He concludes that the heightened contrast is a retinal phenomenon, as it does not arise when the two eyes are stimulated differently. Nagel was so convinced of the importance of heightened contrast in anomalous cases that he constructed some of his cards to take advantage of it, the expectation being that a yellowish dot next to a red one would look green, a grey dot between green dots pink, etc. Nagel claimed that a contrast color might appear on rotating discs, when the inducing color was still subliminal. Grill (37) reports the results of a comparative study of a normal and an anomalous subject using Göthlin's anomaloscope. A monochromatic light was shown in half the field

and a neutral light of equal brightness in the other half. With red the contrast effect was decidedly more marked, with green decidedly less marked, for the anomalous than for the normal observer. With blues and yellows no difference between the two subjects was noted. Lohmann (76) attempts to determine whether contrast is a factor in forming the Rayleigh equation (red plus green equals yellow) in the Nagel Anomaloscope. He arranged the apparatus so the spectral yellow and the red-green mixture could be presented successively and thus not influence each other. With this arrangement most of his anomalous subjects accepted the normal red-green mixture. Further experiments with a Lummer-Brodhun photometer convinced Lohmann (77) that it is fair to attribute heightened contrast to anomalous trichromates. Köllner (70) seeks an explanation of this heightened contrast. Repeating Guttmann's experiments with rotating discs, he reports clear evidence of heightened contrast. He obtains similar results with colored lights. He does not find, however, that the anomalous get contrast from a lower saturation of the inducing color, as has been claimed. In fact, with rotating discs the contrast threshold is higher for the anomalous, a fact which explains their failure to see contrast colors with the Hering window and the Cohn tissue paper test. Köllner attempts an explanation on the hypothesis that color weakness is due to peripheral changes, while contrast is due to central changes. Ordinary objective colors are seen much less vividly by the anomalous, so contrast colors, which are subjective, become overvalued in comparison with the objective colors. The heightened contrast is thus the result of a false judgment, and does not form an exception to the generally conceded lower color sensitivity of the anomalous. Hess (55) thinks it a mistake to speak of heightened contrast and attempts an explanation of the facts in terms of his discovery of red-green inequality rather than color weakness in the anomalous group. For them the purity of colors is different from that of normal subjects. The protanomalous, for example, see green purer than normal, while their yellows and blues are mixed with grey. There are also decided differences in brightness. These conditions might have a great influence upon the perception of contrast colors. Guttmann (41) reports upon a study of after-images made in 1909 but delayed by the war. He had previously discovered that his anomalous subjects got the same after-images as dichromates, the red-yellow-green part of the spectrum giving a blue after-image and the blue-violet end giving a yellow after-image. He now finds that the after-images of his

anomalous subjects last only about 2/3 as long as those reported by normal subjects, and suggests as an explanation the quickness of fatigue to color characteristic of the group.

Several brief reports of experiments upon totally color-blind subjects have appeared. Bender (**3**) used 9 normal subjects and two typical achromates in a study of the luminosity of spectral colors, using a Lummer-Pring spectral flicker photometer. His two abnormal subjects were not only totally color-blind, but had low visual acuity and light-dread. In both cases the place of maximal brightness fell in the blue-green region at about 515 mm. Velter (**107**) reports a case with a light red unpigmented zone in the macula of each eye. Hofman and Nussbaum (**59**) report three cases, one lacking macular adaptation completely, and one showing normal macular adaptation in one eye and none in the other. The authors claim that the macular functioning of the totally color-blind eye follows no definite rule either in bright or in dark adaptation and cannot be used in deciding debated questions of color theory. Wernicke (**115**) reports two cases, brothers, with only about 1/10 vision, light-dread and vertical nystagmus. Crosland (**15**) reports experiments upon a totally color-blind subject with myopia, astigmatism and strabismus of the right, weaker eye, but makes no mention of light-dread or nystagmus. In sorting wools and comparing them with a set of 50 Hering greys, the subject tended to put the yellows into the lighter groups and the greens and blues into the darker groups, thus failing to show the Purkinje phenomenon. Hess (**58**) claims that he does not find foveal blindness in the totally color-blind, that his cases do not become blind in a bright light but close their eye-lids part way to see better, and that various phenomena occur in light and dark adaptation which are not readily explained on the Von Kries hypothesis that the totally color-blind are "rod-seers." Engelking (**30**) reports upon a special study of eye-motor reactions under various conditions of light adaptation. Flash light pictures of the totally color-blind show certain characteristic positions of the lids and the eye-balls under stimulation with different colors, the lids being nearly shut and the eyes turned upward in response to bright grey or yellow-green, the lids half-shut and the eyes half-exposed with dark grey or blue, and the lids fully open and the full eye showing with black and red. The width of the pupil varied similarly according to the brightness of the stimulus color, giving motor values in the Hess Differential Pupilloskop which form the extremes of a series including normal, protanomalous, protanope and totally color-

blind. In adaptation the totally color-blind react very differently from the other types, however. After dark adaptation the pupils of the totally color-blind react to strong light as much, though more slowly than the normal; after bright adaptation followed by dark adaptation, the pupils of the totally color-blind open much more slowly than do the normal and the partially color-blind. All the other types react in much the same way, leaving the totally color-blind in a class by themselves—a fact which may perhaps be explained on the duplicity theory according to which the totally color-blind have only a twilight apparatus which adapts itself much more slowly than the daylight apparatus to changes in illumination.

Robinson (90) gives a detailed report of experiments with Holmgren wools, Hering colored papers, the Nagel Cards and spectral lights with a blue-yellow blind subject concerning whom she had published a brief account ten years before. She gives abundant evidence for her general conclusions: that this subject is insensitive to blue and yellow as colors, while showing fair sensitivity to red and weak sensitivity to green; that his spectrum is not shortened and has its maximum brightness in the colorless blue region; that his color defect has a congenital basis.

It has often been reported that intelligent color defectives learn to take advantage of secondary criteria in distinguishing colors. Robinson (90) reports that her blue-yellow blind subject noted what he called texture, flatness or smoothness of surface, shade, brilliance, or dullness, and mixture. She had as much difficulty in understanding what these terms meant to him as he had in understanding what blue and yellow were, as colors, to her. Colored or uncolored surfaces, he said, had a texture that grey surfaces lacked. Uncolored surfaces were not well-mixed and flat as were grey surfaces. Orange was a particularly unmixed surface. A mixture containing red was darker in shade than green when both were subliminal, and this shade was sometimes the basis for distinguishing green. Blue was brilliant in surface—had a glint to it—while yellow was dull. Purple and violet were both described as being "thin reds" with the luster that characterizes some blue surfaces. With the help of these secondary criteria he concealed his color-blindness from his friends and even from his students when he was teaching physics in a small high school. A curious illustration of the skill used in following secondary criteria is given in the case reported by Gildemeister and Dieter. (35) An engineer rejected in 1910 because of uncertainty with the Nagel Cards was later examined several times with the

Nagel and Holmgren tests and passed, though the anomaloscope classified him as a typical protanomalous trichromate in 1914. He was further examined with varying results until 1919 when he made no mistakes with colored objects and showed great improvement with the anomaloscope. Since it seemed unlikely that his color sense had improved, tricks were suspected. Could he help himself out by muscle memories? Had he learned, perhaps, that if he turned to a full stop and then went back a certain distance, his equation would be accepted? To get an answer to such questions, the anomaloscope was turned upside down and the knobs adjusted to move in the opposite direction. But he still succeeded with the equation. The authors then concluded that the subject had learned to accept an equation which looked wrong to him, and this assumption was checked up by experiments upon one of the writers who was a deuteranomalous trichromate. This subject was put through a series of daily practice tests and soon learned to pass the test by recognizing and accepting the normal equation although it always seemed wrong to him. And he retained this ability after several weeks without practice during the interval. Kirschmann (**68**) and Roaf (**92**) suggest that by the use of colored glasses or screens slight differences in the sensations caused by colors generally confused may be brought to the attention of color defectives and that by practice they may be taught to distinguish these colors without help.

A few cases of acquired color-blindness are described. Atkinson (**2**) reports observations on snow-blindness in the Antarctic and in Europe, comparing it with the effects of telescopic observations of the sun and the use of the eyes in watching welding operations with high power electric currents. Lohmann (**75**) reports experiments upon two cases of red-green blindness following snow-blinding. Edridge-Green (**25**) tells us that a man recovering from influenza developed red-green blindness which disappeared after five months. Boehmig (**4**) reports color disturbances after strenuous physical exercise sometimes causing central scotoma, which lasts as long as twenty hours in extreme cases. He assumes a pathological activity of fatigue poisons upon the pupillary macular nerve bundle. Wölfflin (**119**) finds that by the use of caffein and strychnine the threshold for red may be lowered for deuteranomalous trichromates, while sensitivity to green, yellow and blue remains unchanged. In two deuteranopes the sensitivity to yellow was distinctly raised. He used and commends Engelking's "peripheriegleichen Farben"—colors of equal brightness and saturation which show no color changes

in passing from periphery to fovea. Engelking (27) reports the successful use of these colors in the study of the gradual constriction of the color zones in acquired color defects. Eliot (26) reviews a number of cases in which alterations in color perception and in color fields followed quinine poisoning.

The question of the classification of color defects is engaging the attention of many students. Troland (106) sums up the general state of affairs. "There appears to be a great deal of uncertainty at the present time regarding the exact number of congenital forms of color-blindness, and it is to be hoped that some careful student will undertake to sift out the really characteristic types, to evaluate the evidence for and against their hereditary origin, and to determine their statistical relationships to fluctuations in the normal type. . . . It is obvious that the original restriction of color-blind types to protanopes, deuteranopes and tritanopes is no longer adequate, and we must make allowances in our color theories for more types of variation than are indicated by primitive considerations concerning the visual mechanism." Allen (1) attempts a classification based directly on the Helmholtz theory. Since we have proved the fundamental sensations to be red, green and violet, he says, there must be seven main types of color-blindness, three with one color missing, three with two colors missing and one with all three colors missing. Edridge-Green (20) feels equally sure of quite a different classification into seven types based upon his records of the number of distinct colors which can be seen in the spectrum. Hess (58) has made a serious attempt to determine, by the use of new and improved methods, the exact differences in color sensation experienced by various color defectives, aiming to measure the degree of color defect as exactly as we can now measure degree of visual acuity. He presents the following classification: Subjects may be slightly over- or under-sensitive to any color and still belong to the "normal" group. Hess quotes the case of an eye specialist who had long been a railroad examiner. This man was over-sensitive to red with normal sensitivity to green, and this red-green inequality showed itself in several tests. He could not pass the Stilling test and in the Nagel Anomaloscope the normal equation looked very red. He reported that during the war he was able to recognize colored enemy fireworks better than his associate officers. In a spectral test he could see beyond the normal limits for red. Another subject showed extremely high sensitivity for green. Hess thinks that many anomalous cases have been wrongly classed as color-weak because they do not accept the normal

Rayleigh equation, when all that this proves is color inequality, which may result from supernormal sensitivity to one color. But there are also cases in which normal sensitiveness to one color is associated with subnormal sensitiveness to the other. Hess would call these subjects red-sighted and green-sighted, preferring these terms to the customary deuteranomalous and protanomalous since these are based on a three color theory and carry incorrect connotations. The red-sighted require less red than the normal subject in the Rayleigh equation, have a wider than normal field for red and a narrower than normal field for green, and show higher than normal motor values for red. Their sensitiveness to blue and yellow is about normal. The green-sighted require less green in the Rayleigh equation, have a wider than normal field for green and a narrower than normal field for red, and lower than normal motor values for red. Their blue and yellow zones are generally constricted but they sometimes have higher than normal motor values for blue. For the two classes of dichromates, Hess prefers the names red-blind and green-blind, as the special deficiency of one color is the primary characteristic. The green-blind suffer a less serious disorder than the red-blind; although unable to see either red or green, their threshold for blue and yellow is equal to normal and their blue-yellow zone equal or superior to normal. Their motor values for red and blue are generally normal. The red-blind approximate the totally color-blind in various respects. Their threshold for blue and yellow is raised, their blue-yellow zone is constricted, their motor values for red are low and for blue higher as in total color-blindness, and they have a shortened spectrum with displacement of maximal brightness to the blue-green region. Hess cites six lines of evidence indicating that the red-blind are relatively under-sensitive to blue and yellow, like a dark adapted green-blind and occupy an intermediate position between the green-blind and the totally color-blind.

The wide diversity of opinion upon the question of the classification of color defectives may be partly explained on the basis of rival color theories; but a second factor of great importance is the enormous individual differences in the subjects studied, making it seem almost equally reasonable to class some subjects in either of two groups. An excellent example of the range of individual variation may be found in the tables presented by Franke (32), in which are included the Rayleigh equation readings in the Nagel Anomaloscope for twenty-seven doubtful cases and for twelve anomalous trichromates. Malling (79), using a Helmholtz color-mixture apparatus,

tells the same story. He finds some departure from normal sensitiveness in a large per cent of his subjects and surmises that sooner or later it may be possible to show a complete series of transition forms from the normal through all types of color defect to complete color-blindness. His chart showing the variation in position and breadth of the neutral zone in a series of cases, points definitely toward such a result. Collins (12) finds individual variations in all her different tests and gives the results in an illuminating comparative table of her ten dichromates tested in twelve different ways. After an unsuccessful attempt to picture her cases in diagrammatic form she concludes that so many individual types exist that "it is unprofitable to try to systematize the color sensations of the color-blind." Hess (58) constantly emphasizes the wide variations in sensitivity not only to red and green but also to blue and yellow, and cites numerous cases in which sensitiveness to one color or to a pair of colors varies independently of sensitiveness to the rest. Within each group cases may not be closely alike, so it is dangerous to generalize from one or two cases which may not be representative. Between types he finds transition forms which are not easily classed in either group. Hess (56) marshals five distinct lines of experimental evidence to prove the existence of transition forms between partial and total color-blindness. One wonders if we shall presently have to give up all classification by types, arrange color defectives in distribution tables and give a color graph or profile for each subject showing his efficiency or deficiency for each color in terms of a per cent of the normal or average attainment. Engelking (31) agrees with Hess in claiming that deuteranopes and protanopes are radically different and that protanopes share certain deficiencies with the totally color-blind. But he finds a marked difference in the brightness curves of the last two groups, and notes other peculiarities of the totally color-blind which are not found in protanopes, such as reduced visual acuity, slower widening of the pupil with reduced lighting and a lower fusion frequency. Köllner (72) supports Hess in his classification and in his conclusion that the normal green-blind, red-blind and totally color-blind form a definite evolutionary series of progressively more serious color defects, but with no transition forms between the green-blind and the red-blind. The anomalous groups give the greatest difficulty to the practical examiner and the emphasis Hess puts on red-green equality and inequality points to a solution; for while the anomaloscope detects those with red-green inequality it fails to discover those who are equally insensitive to red and green.

Such subjects may be as dangerous as dichromates and some further method must be used to keep them out of service where color discrimination must be normal. Von Kries (74) finds the review Hess makes of the last twenty years of progress in the study of color vision so one-sided and erroneous that he cannot let it pass without protest. He publishes an extended treatment of the whole subject of color vision from the point of view of the duplicity theory. Oloff (86) takes up the cudgels in defense of Hess especially on the question of practical color testing. He gives an interesting historical review of the rise and fall of the Nagel methods. Oloff thinks diagnosis is not possible with pigment tests. For preliminary surveys he still values the Stilling, Nagel and Cohn tests and thinks very highly of Podesta's Tables but insists on the use of the anomaloscope in all doubtful cases. While greatly impressed with the new equation methods devised by Hess, he does not approve of their general introduction until after a long period of trial. Candidates should not suffer from further defective methods!

The heredity of color defects has engaged the attention of various writers. Cole (11) gives genealogies for some old cases and Vogt (112) for some new ones. Several other writers have made important contributions involving extensive collections of published genealogies and the presentation of elaborate new ones in which all accessible members have been carefully tested by approved methods and the results interpreted with reference to the biological laws of heredity. Schiötz (95) reports upon a survey in which about 3,000 school boys, recruits and railroad men and over 2,200 school girls were tested. He used a battery of tests including the Holmgren and Daae wool tests, the Cohn contrast card, the Nagel Cards, the Stilling, Ishihara and Podesta Tables and the Nagel Anomaloscope. He claims to have tested 500 color-blind men and 40 color-blind women in the course of his work. After a review of the published genealogies and a comparison of these with his own, he concludes that "if we assume that color-blindness is a recessive character in Mendel's sense, and that the gene for color-blindness is carried by the sex chromosome, then every obscure feature of its inheritance becomes perfectly clear." Vogt and Kleinguti (113) report upon a systematic study of the students in girls' schools. Among 2,238 subjects varying in age from 11 to 16 years they discovered 9 color defectives. The Stilling Plates were used by daylight in the school rooms and all doubtful cases were taken to a clinic where further tests were made with the Stilling Plates, the Holmgren Wools and

the Nagel Anomaloscope. The heredity of six of the color defectives was carefully worked out and so far as possible the living members of their families were tested. The authors present complete genealogies and anomaloscope readings for 17 color defectives in these 6 families. In two families it seems clear that the mother must have been a "conductor" of color-blindness, and in no case is there testimony adverse to Horner's law, that color-blindness is transmitted from fathers through unaffected mothers to grandsons. Both deuteranopes and protanopes were identified but the hereditary relationship of the two types is not clear. Schiöts reported that so far as he had tested he had always found the same type of color-blindness in a family. Wölfflin (119) gives a genealogy in which deuteranopes and deuteranomalous trichromates appear in succeeding generations. Hess (58) finds three methods of inheritance and cites instances: the same defect in successive generations (father and daughter both green-blind, with normal sensitivity to blue and yellow); the same type of defect, but in different degrees, among siblings (two green-blind brothers, one with normal, the other with supernormal sensitivity to blue and yellow); different degrees of a defect in different generations (red-sighted father with two equally red-sighted daughters and a green-blind son all having normal sensitivity to blue and yellow). Hess says he has seen no family in which there were both red-blind and green-blind cases, nor any descendants of red-sighted who were green-sighted or red-blind. He feels particularly sure of his cases because of the "objective" evidence obtained by his Differential Pupilloskop. His families, however, do not fit the hereditary pattern now commonly assumed. Döderlein (18) gives an excellent review of the literature to date. He suggests that the particular difficulties mentioned by Hess—that defects seem to descend from father to son and that there are differences in degree in succeeding generations—may be overcome by a more extended study of these families, as it is possible that the inheritance may have come through mothers who were conductors, and not immediately from the defective fathers. In his own genealogy he finds a red-sighted father passing the defect to a daughter, while the wife who was descended from a family showing green-blindness passed this type of defect to her sons. In view of the unsatisfactory methods often employed and the incomplete genealogical evidence in many families reported, Döderlein undertakes to advance the science by a complete study of the Döderlein and Schoen families. These two families have intermarried and in both strains there are color

defects—red-blindness and red-sightedness. Some of the subjects knew of their defects only after extended experimentation. All members of the III, IV and V generations were tested by Döderlein or his colleagues except two cases who were deceased and judged to be color-blind on the testimony of near relations. Döderlein himself used the Hess Tunnel Modell and Differential Pupilloskop, the Nagel Anomaloscope, rotating discs, a perimeter and a solar spectrum with 40 members of the two families. He suggests that since the study of human heredity is so slow we might accelerate matters through a study of animals. It is easy to recognize types by the use of the Hess Pupilloskop and to obtain objective results with animals as well as with human beings. We might well test a large number of hens and monkeys and after discovering color defects like those found in human beings, the appearance of these defects among the progeny of controlled breeding might well solve the problem for human beings.

The heredity of total color-blindness also has been studied recently: Wernicke's (**115**) two cases were brothers; Velter's (**107**) two cases were a brother and a sister; Waardenburg's (**114**) two cases were a brother and sister, the children of cousins. Waardenburg appeals to physicians to accumulate data on the heredity of total color-blindness. Vogt (**112**) says that total color-blindness is supposed to be very rare in Europe, but that this scarcity may be more apparent than real. He found three cases during the examination of 4,000 children in the Basle schools. The only previous cases reported in Switzerland were three found by Pflüger in 1898 in a Grundelwald family of ten members. He thinks cases may have been overlooked because poor vision is the primary defect and oculists may not have tested their cases for color sensitivity. Vogt's three cases belong to three separate families having no relationship to each other, and no other cases could be discovered in any of these families. Vogt thinks total color-blindness is recessive and that the consanguinity of parents plays an important rôle in its production. Kleinguti (**69**) reports a careful study of a family in which 4 out of 7 children have retinitis pigmentosa, nystagmus and total color-blindness. In this family, as in one of the three reported by Vogt, there was consanguinity of parents and Kleinguti concludes that both retinitis pigmentosa and total color-blindness are recessive characters which appear only when inherited from both parents. He opposes the recent suggestion of Hess that protanopes represent a transition stage between deuteranopes and the totally color-blind since

protanopes show none of the most characteristic defects of the totally color-blind—foveal blindness, nystagmus or light dread. They do approximate the totally color-blind in pupillimotor values and in the shift of brightness to the blue-green region.

Recent surveys tend to support the common claim that partial color-blindness is about ten times as frequent among men as it is among women, though there is considerable difference of opinion as to the absolute frequency of each, depending upon the tests used and the method of classification employed. Schiötz (95) found 10 per cent among 300 males and just under 1 per cent among 2,200 females tested. Vogt and Kleinguti (113) found only 0.4 per cent among 2,200 girls, and put the frequency for men at 4 per cent. Franke (32) found 8.5 per cent among 750 men and Taylor (100) found 5.4 per cent among the 1,000 men tested in N. S. Wales. Collins (12) found only .6 per cent of girls and 1.9 per cent of boys in a survey of over 1,000 Edinburgh school children including about equal numbers of boys and girls from 9 to 12 years of age.

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VISUAL ILLUSIONS, WITH SPECIAL REFERENCE TO SEEN MOVEMENT

BY PAUL C. SQUIRES

University of Vermont

The configurational doctrines have risen proximately from the experimental investigations of apparent movement. The researches carried out by the Gestalt psychologists within the field of the perception of movement have demonstrated in what manner functional relations obtain in configurational phenomena. The principles brought forward by the configurationists to elucidate the phenomena involved in the perception of movement have been elaborated by them to cover the entire range of perceptual facts.

Considerable investigation had been accomplished previous to the now classical research of Wertheimer (**90**). In the various theories formulated prior to Wertheimer's work of 1912, the assumption is inherent that the perception in question can be broken up into simple constituents which can then be brought into correlation with the stimuli. None of these older theories treats of the sufficient and necessary conditions underlying every kind of perceived movement whatsoever. Such theories were prominent as those couched in terms of fusion of after-sensations (Marbe), in terms of eye-movements (Wundt), and in terms of a highly specific sort of sensory process (Exner and Stern). F. Schumann suggested an experiment by means of which to demonstrate the simplicity of the movement experience (*Ber. ü. d. II Kong. f. exp. Psychol.*, 1907, **218**) and Wertheimer followed up this suggestion. The chief stimuli utilized by Wertheimer were two parallel horizontal lines and two lines situated at an angle to each other. There was reported the isolation of a bare movement-experience, called by Wertheimer the phi-phenomenon. This movement-experience does not possess visual quality but only spatial localization and direction. Due to the fact that he failed to find filling-in of the field of movement, Wertheimer maintained that a cortical short-circuit must be the physiological correlate of the perception of movement. The pure phi-movement involves no perception of a founding process, or of color or line.

The pure Phi is given the following characterization by Wertheimer: " Im Gegensatze zu anderen psychischen Gegebenheiten sind sie nicht statische sondern dynamischer Natur; in dem spezifisch characterisierten 'Hinüber' usw. haben sie ihr psychologische Fleisch und Blut, nicht zusammensetzbar aus dem der üblichen optische Inhalte." (p. 227.)

Schumann (75) contributed markedly to the setting of the configuration theory. He investigated, before the work of Wertheimer had been accomplished, apparent movement as it is obtained tachistoscopically with such geometrical figures as the Müller-Lyer illusion. Schumann reported that occasionally the " object " seemed to " drop out "; there was sometimes merely an " Etwas " that " sich hinüber bewegt." " Wenn ich von einem sinnlichen 'Etwas' sprach, das bei stroboskopischen Versuchen zu den Wahrnehmung-bildern hinzukomnt, so habe ich damit nicht einen Bewusstseininhalt gemeint, der durch Prozesse in der Netzhaut hervorgerufen wird . . . nur ein zentraler Vorgang in Frage kommen kann. Er lies von zwei rasch aufeinanderfolgenden, räumlich benachbarten Gesichtseindrücken jeden nur auf ein Auge einwirken, und doch war der deutliche Eindruck der Bewegung da " (p. 183). Kehr (42) has emphasized that the phenomena of apparent movement are to be subsumed under the phenomena of perception in general and are of such a nature as to illustrate the entire field of perception. Kenkel,(43) working under the direction of Koffka, has described three species of apparent movement, designated by him as the alpha, the beta, and the gamma movements. The alpha movement rests upon illusory differences in magnitude, such as are found strikingly in the Müller-Lyer figure. The beta movement involves real, objective divergencies in the size of the stimuli. The gamma movement denotes the expansion and contraction within a given figure when it is briefly exposed in a tachistoscope. Koffka (44) sums up the contributions of Wertheimer as presenting three outstanding phases: first, descriptive; second, functional; and third, physiological. Koffka (46) brings forward the hypothesis to the effect that the gamma movement of Kenkel is expressive of a structural process. The radiation of nervous excitation is the condition of the expansive movement, while the flowing inward, the concentration of the cortical excitation, is the condition underlying the contraction observed as one of the phases of the gamma movement. The more intense the illumination the more marked the gamma movement, and conversely. In another article, Koffka (47) would maintain that the work of Lindemann has dem-

onstrated the validity of the Koffka hypothesis concerning the essential nature of the gamma movement of Kenkel. Koffka (45) has elaborated the Wertheimer theory by giving a geometrical formulation to the supposed central nervous processes that are occasioned by the stimuli. He furnishes a mathematical statement of Korte's laws. Difficulties are encountered due to the fact that one stimulus may be effective without the other, discrete processes being the correlates of the movements. Koffka shows that a far more extensive and complicated theory is required to explain the various phenomena of apparent movement than the one formulated by Wertheimer.

Korte (50) investigated what he termed the delta movement. The delta movement involves a large number of conditions, among which the point of fixation and the distribution of attention are cardinal. The delta movement, otherwise known as the reversed movement of Korte, consists in apparent movement backward from the second to the first stimulus member. Korte believed that this reversal of movement was directly conditioned by intensifying the second member and placing it in the focus of attention. Intensification of the stimulus was accomplished by increasing the width of the second as compared with that of the first member; also, the intensity of the second stimulus-member was heightened by adding short perpendicular lines to its ends. Both the conditions of intensity of the second member, and directing the attention to this member, were requisite for the production of the delta movement. Korte, (51) assuming that subjective factors are constant, varied the objective factors for the purpose of demonstrating the dependence of apparent movement on these objective factors. The assumption of the constancy of subjective factors was a most precarious one. The objective factors controlled were the time of exposure of and between the stimuli, the difference in brightness of the stimuli, the spatial distance between the stimuli, and the size of the stimulus-members. The relations between various combinations of these objective factors and the beta and delta movements were studied. Korte finally enounces three laws, each law being formulated in two distinct ways.

Koffka (48) gives an account of the investigations carried out under his supervision by Annie Stern (79). The problem concerns the perception of movement in the region of the blind spot. Three major conclusions are drawn: first, the blind spot is relatively, but not completely blind, it being very insensitive to light stimulation; the sensitivity increases slowly from the center to the margin. Second, this sensitivity is far higher for double exposures giving rise to

movement-process than for single or simultaneous double exposures. Third, these movement-impressions cannot be explained by "higher psychological functions" superposed upon the simple sensations, in view of the fact that these "simple" sensations cannot be generated. These experiments on apparent movement in the region of the blind spot were repeated in a rough manner with real movement, the identical results being obtained. The movement described the same curves, whether the movement was real or apparent. The fact is stressed that the "subjective" visual field is always heterogeneous even under those situations where the objective conditions are everywhere the same. Linke (**58**) maintains that he was the first one to furnish a descriptive account of the Wertheimer movements. The intimation is thrown out that all that Wertheimer has done is to transform the terminology. He says: "Meinen 'unmittelbaren Bewegungseindruck' nannte Wertheimer das Phi-Phänomen, meinen 'stroboskopischen Effekt' das Optimal Stadium, meinen 'thaumatropischen Effekt' das Simultan-, meinen 'Ruheeffekt' das Sukzessivstadium" (p. 262). Linke (**59**) represents the extreme phenomenological position, insisting that the phenomena involved in the perception of movement must be explained by reference to purely psychological factors and principles. Reference to the mechanics of the nervous system does not clear up the movement-experience. Movement is a function of "assimilative perception"; this concept should not be confused with the Wundtian concept of assimilation. The sensory data within a given perception are completed by the entrance of pre-perceived elements. A multiplicity of place-determinations or a succession of phase-images constitutes movement. That which moves is the object which is identified in the various phases. Linke considers this to be a real psychological explanation, and the only one that ought to be accepted. The inadequacy of Linke's theory is well brought out by the investigations of Gelb and Goldstein (**26**) who discovered a subject who was capable of perceiving a moving object in successive phases only; each of these phases was stationary. Although the subject realized that the various phases belonged to a single object, *no movement was perceived*. This clinical fact would appear to be incompatible with Linke's phenomenological theory of apparent movement.

Benussi (**5**) studied the kinds of apparent movement investigated by Kenkel. He regards them as "suprasensuously" conditioned phenomena and considers them to be illusions. A synthesizing attitude is requisite for the perception of an illusion. The relation

between the synthetic and the analytic attitudes is expressed by the law of double exercise: practice in the synthetic attitude is accompanied by fatigue in the analytic attitude, and conversely. Benussi discusses inadequacy carriers in illusory patterns. Examples of these inadequacy carriers would be the feathers and arrowheads in the Müller-Lyer illusion. The alpha movement is strengthened by whatever factors favor illusion in the static figure. The alpha movement can be voluntarily suppressed by the assumption of an extreme analytic attitude. Kenkel has not mentioned this latter point. F. Schumann had already shown how a totalizing attitude accentuates illusions. Benussi (6) worked over the experiments of Wertheimer in the modalities of vision and touch, using twenty-seven observers. Benussi states that experience gives no pure movement in the sense of a movement without an object. Although attention is a necessary condition of illusion, it is not, however, a sufficient condition.

Cermak and Koffka (11) investigated the problem as to whether the Korte laws obtain when the space interval between successive phases of the stimuli decreases, or when more than two phases are in succession. It is assumed that if the distance between phases is reduced to zero, there will be an identity between apparent movement and light mixture. The Korte laws with the exception of the third were found to be valid when the light frequencies were high. Cermak formulates the "zone" law in order to dispose of the difficulties presented by the third law of Korte. Eight laws are formulated by Cermak. These laws apply to light mixture and apparent movement, and are designated as the parallel laws. By means of these laws is expressed the interdependence of the factors involved in the phenomena of apparent movement and fusion. Both fusion and apparent movement are conditioned by a common set of underlying factors and a theory must be erected that will include both types of phenomena. Similar, probably identical, configurational processes are at the basis of both fusion and apparent movement. The range of application of the laws of Korte is more extensive than Korte himself believed. Hartmann (29) experimented on the fusion of two figures when tachistoscopically exposed in succession. The conclusion is drawn that the alpha and beta movements, together with the various degrees of fusion, are included in the same set of laws. The foundational laws are those of Korte and Cermak.

Hillebrand (37) enters into a severe criticism of the Wertheimer cortical theory. The Wertheimer phenomenon involves the factor of "absolute" localization. This factor depends upon attention; a

transference of the point of attention gives rise to a revaluation of space values. Stroboscopic movement expresses the progression in a continuum from no valuation to complete revaluation. The process of revaluation and perception of apparent movement are correlated. Although the time interval may be zero, optimal movement may be perceived. Hillebrand insists "dass man selbst ohne Zwischenpause Ganzbewegung erzeugen kann" (p. 244). Hillebrand (**38**) also treats of the conditioning influence of alteration in the magnitude of the excitation on apparent movement. He advances a proof for the shifting of the visual field in the case of stroboscopic movements and gives a summary of his theory. There are two appendices that consider the theories of Wertheimer, Koffka, and Linke, and that give an account of the experimental technique utilized by Hillebrand. Watt (**89**) is most critical of the Wertheimer theory when he states that the Wertheimer theory "makes no contribution to psychological theory" (p. 26). Watt attacks the Wohlgemuth theory of visual motion; this theory is a physiological one. A *psychological* classification and theory is needed. The Wohlgemuth theory begs the question.

Dimmick (**13**), in this investigation, tends to confirm the descriptive facts of Wertheimer. The Wertheimer simulus objects were used, together with six new objects. Both "process" and "meaning" instructions were used. The primary purpose of the investigation was to subject the phi-movement to descriptive conditions of a critical nature and to determine its susceptibility to analysis. The phi-phenomenon assumes the form of a primary integration of a visual quality (grey) with a duration that is characteristically brief. The grey, which is the psychological equivalent of the seen movement, does not depend for its quality upon the quality of the stimulus members; however, it evidences the influence of background. This influence is of the order of a brightness-contrast effect. The reverse movement of Korte was also investigated. The Wertheimer and the Korte movements do not belong to the same order. To the Korte conditions Dimmick added intensive insistence. The Korte delta movement does not confront us with compulsory conditions. Dimmick and Scahill (**15**) found that the earlier research of Dimmick was confirmed in respect to the movement process pattern assuming the form of a "filmy grey flash." There is no difference in kind between the perception inaugurated by a moving stimulus and that initiated by non-moving stimuli. The process patterns correlated with the two types of stimuli are to be distinguished only by reference to

the modes of distribution of the various degrees of intensity within the patch of grey, *e.g.*, greater or less uniformity. The compulsory conditions of the perception of movement do not, therefore, include actual physical motion of the stimulus.

Higginson (34) found, among other things, that complete movement is uncorrelated with any specific time interval between the stimulus members, and that insistent apparent movement can arise although the temporal interval is zero. Higginson rejects the Wertheimer notion that a particular temporal pattern is required for the arousal of the phi-phenomenon. Moreover, the significance of the visual grey considered by Dimmick to serve as the psychological correlate of visual motion has been exaggerated. There is a utilization of nonvisual resources to a far greater degree than either Wertheimer or Dimmick recognized in their work on apparent movement. "The visual apprehension of movement under discrete retinal stimulation is a form of abstractive perception determined by stimulus, receptor, and central organ, the degree of abstraction depending upon the availability of experiential items and upon the relative contributions of environmental and organic factors."

Dimmick (14) gives a very brief discussion on the investigation of Higginson that has been touched upon in the above paragraph. This is an answer to the criticisms brought to bear by Higginson against Dimmick's work on visual movement and the phi-phenomenon. Dimmick's rebuttal of Higginson's criticisms is threefold: First, since the experimental conditions of the two investigations were noncomparable, the results are noncomparable, and hence Dimmick's results cannot be criticized upon the basis of Higginson's findings. Second, the problem in the two researches is different for the two researches. Third, Higginson has disregarded and misinterpreted the explicit statements of Dimmick. Higginson (35) in a recent article discusses the rôle of ocular movements in stroboscopic perception. He investigates the notion which denies any significance to eye movements, this notion being founded on the theory that the time interval between the presentation of the stimulus members is altogether too brief for the occurrence of eye movements. Higginson asserts that it is a mistake to deny the significance of eye movements in stroboscopic movement and points to Korte's research: Korte has demonstrated that phenomenal movement and physical sequence may be in opposed directions. Nine lines of evidence are advanced by Higginson to show that eye movements often occur under the condition of discrete retinal excitation. These nine evi-

dences indicate eye movements as constituting a common condition for the perception of apparent movement. However, it is not maintained that eye movements are the principal determiners of seen movement under successive stimulation. Eye movements in stroboscopic experimentation require far more efficient control and recording than they have received in the past.

Higginson (36) points out aspects of configuration theory that seem to stand in contradiction to the experimental data. Gestalt Theorie is at its weakest in its interpretation of visual motion. Nine groups of phenomena within the field of apparent movement are formulated by Higginson. He asserts that these phenomena are not to be understood in terms of present-day Gestalt doctrines; short-circuiting, differences in potential, and cortical fusions are inadequate for the explanation of the facts. The conclusion offered in the first part of the investigation is that the physiological theory advanced by the Gestalters to explain phenomenal movement must either be completely cast aside or must be reinterpreted. The second part of the study deals with the effect of colored stimuli upon the perception of stroboscopic movement. Wertheimer had maintained that there is a contingent relation between the perception of apparent movement and the stimulus quality. Higginson, on the contrary, finds that the dependency between the color of the movement and that of the stimulus members is an absolute one. Apparent motion is not to be divorced from the hue of the moving object. The character of the apprehended movement may be altered by a shift in the hue or hues of the stimuli: when the stimuli are different in color fewer instances of optimal movement occur. Perhaps this latter fact indicates that movement continuity is disturbed by lack of identity between stimulus members. Higginson would add quality to the conditions determining apparent movement; the configurationists have postulated three conditions only, namely, spatial interval, temporal interval, and intensity. If colored stimuli are utilized for setting up discrete retinal excitations, the existential correlate of apparent movement is not grey.

Koehler (49) has given a restatement of the Hartmann theory of fusion and apparent movement, and has enounced a "subpsychophysical absorption" theory for the purpose of explaining phenomenal movement and fusion in their various stages. Kuile (52) formulates an analysis, in mathematical terms, of apparent movement arising when a binocular fusion between two simple, harmonic, and synchronous movements occurs, the movements being presented to

the eyes independently. The motion, produced stereoscopically, assumes any one of the following orbits: circular, elliptical, or hyperbolic. The relative velocities of the apparent movements are calculated for different points on the paths of motion. Lasersohn (53) discusses the position of Exner on the general problem of visual movement. An experiment is described that was worked out in the Schumann laboratory. "Wenn nämlich zuerst ein kleinerer und unmittelbar darauf ein grösserer konzentrischer Kreis exponiert wird, so kann man noch dem inneren Erlebnis dadurch Ausdruck geben, dass man sagt: 'Es schien ein kleinerer Kreis sich zu einem grösseren auszuweiten'" (p. 121).

Lindemann (57) made a further investigation of the gamma movement that tended to confirm the findings of Kenkel. However, the gamma movement is not conditioned solely by attention. Fixation and attention carry opposite effects: attention favors, while fixation tends to destroy movement. In figures which have sharply pointed as well as rounded parts the movement is weaker, less insistent toward the rounded than toward the pointed parts. This phenomenon has a striking analogy in the field of electricity, where a current displays a strong tendency to flow toward a point. Third dimensional movement was manifested by figures that were drawn in perspective. The direction of movement is equivocal providing there exists an equally easy road to two configurations. Time of exposure determines the apparent size of an object. A figure, when apprehended as a *thing,* displays the tendency to remain static; but when the same figure is apprehended as a mere surface the gamma movement arises. Lindemann states his conclusion in complete keeping with that configurational principle which enounces that all configurations manifest the tendency to become "as good as possible" as to their structuration. Rothschild (71) investigated the appearance of patterns when they were passed across vertical slits in a horizontal direction. High velocities narrow the appearance of the figures, but low speeds broaden them. Eye movements are not operative in determining this effect. Through the use of both equivocal and unequivocal figures it is demonstrated that contour, and figure and ground, are the outstanding conditions of the phenomena in question. However, Rothschild does not explain why it is that a pattern, although phenomenally narrowed, may appear broader than the diaphragm through which it is viewed. Scholz (74) tested out the Korte laws in the fields of vision, touch, and audition. Scholz did not utilize Korte's method. Korte's laws are considered

to be valid. Study is made as to how spatial extent is modified by temporal interval and how the beta movement is affected by variations in spatial and temporal intervals.

Wittman (92) indicates an interesting phenomenon that is sometimes connected with the nature of the time interval between successive stimulus members. He states that for a skilled observer "tritt die Dunkelpause immer mehr zurück, das soeben exponiert gewesene Bild besitzt eine noch erhöhte psychische Präsenz bei Eintritt des neuen Bildes, so dass der Eindruck entsteht, als beginne die 'Bewegung' schon während der Exposition des ersten Bildes und dauere während der Dunkelpause an; dieser Eindruck wird noch verstärkt bei Verkürzung der Dunkelpause, wenn sich die Bewegung dem sog. Optimalstadium nähert; jetzt ist die Präsenz zweier Bilder bei gänzlichem Uebersehen der Dunkelpausen noch wesentlich erhöht" (p. 23). Ehrenstein (18) considers the nature of intrafigural movements. These movements involved changes in the phenomenal magnitudes of the figures. Intrafigural movements are the chief condition of the divergencies between objective and phenomenal form and size. Study was made of the dependency existing between optimum decrease and increase and velocity of motion and magnitude of the angle. Movements of the after-sensation were experimented upon through the use of logarithmic spirals. When contours evidence intrafigural apparent movement on account of a displacement of the retinal image, the contours likewise are subjected to an apparent displacement or shifting of position toward the movement phenomena. The problem of contrast is considered. Actual movement in one part may bring about phenomenal movement in a contrary direction. The contrast effects, however, were not predictable to any significant degree. Central factors play a dominant rôle in the production or nonproduction of contrast effects in the field of movement. Ehrenstein (19) utilizes the facts of phenomenal intrafigural movement in attempting to explain a number of visual illusions. Eye movements accentuate these illusions, while painstaking fixation diminishes or completely destroys them. The experiments carried on in Ehrenstein's research mentioned in the paragraph above were carried further and worked out on nonangular figures. Color alterations were observed, which were to be interpreted as partly mixture and partly contrast phenomena. There also occurred contour changes due to contrast arising from edge against background, and from phenomenal intrafigural movements. It was also noted that the most impressive, insistent aspect or part of a figure

underwent a relatively slow shifting in the visual field. Ehrenstein (20) describes an experiment in which a small, black, circular area, drawn on the back side of a piece of paper, is objectively concentric with a much larger circle drawn on the front side of the same piece of paper. When this pattern is quickly passed across an illuminated slit in a screen, the black circular area is no longer perceived to be concentric with the large circle, but is drawn out toward, or even beyond, the boundary of the large circle. Carmichael (9) describes the construction and use of a simple apparatus for the demonstration of apparent movement; the apparatus may be used for purposes of classroom demonstration. Carr (10) has related some novel experiences connected with positive after-images of motion. Prof. John B. Watson was the observer, the experiment being conducted in 1906. A highly realistic positive after-image of the human eye, in all its details, was developed under darkroom conditions. On account of the striking substantiality of the image it could scarcely be called ghost-like. Neither eye movement, eye closure, nor diversion of attention destroyed its lifelike appearance. A wink of the reflex order was observed after the experience had acquired a duration of some three minutes. Experiments were conducted in which the image of the eye rotated several times. Success in these experiments was made possible by inducing a general ocular fatigue. The after-image did not arise until the stimulation had ceased for from two to three minutes. The image as a rule persisted from five to six minutes. Eight to ten minutes might elapse between the original perception of motion and the after-image of motion. Carr advances the concept of rivalry as the best explanation of the observed phenomena. The rotations and winkings of the phantom eye are the novel aspects of the investigation. Hunter (40) investigated the after-effect of visual movement. Visual after-motion is highly complex and is not to be explained by reference to any single condition. Production of visual after-movement is conditioned by changes in the retinal field—probably assuming the form of fading after-images—by associative factors, and by tensions in the eye muscles. One of these three factors may dominate in a given case. Retinal changes are chiefly responsible for after-motion set up by a rotating spiral. All three conditions are involved in after-motion of lines situated parallel to each other. Phenomenal movement of a stationary system of parallel lines is conditioned by asymmetrical ocular muscle strains. Anomalous results are obtained when the eyes are subjected to movement of large extent, the stimu-

lating objects being parallel lines. In this case two movements are observed: one movement goes in the same direction as does the real movement, while the other travels in the opposite direction. Hunter cannot interpret these effects. Hunter (41) investigated the determining influence of retinal factors in the production of visual after-motion. He concludes that (so far as the retina is concerned) a streaming phenomenon is the ground of the perception of visual after-movement. The streaming takes place in a direction that is in opposition to the direction of the real movement. The streaming phenomenon may be essentially lymph currents, as suggested by Ferree, or it may be electrical in nature. Although its status is undetermined, its existence must be postulated.

Thalman (82) investigated the after-effect of seen movement when the entire field of vision was filled by a stimulus in motion. He repeated the work of A. Wohlgemuth, which was published in 1911. Wohlgemuth held that "no after-effect is produced by an objective movement occupying the whole visual field." Thalman finds that the after-effect occurs even though there is a complete filling of the visual field by an objective stimulus in motion. Duration of stimulation is the conditioning factor in the after-effect of seen movement. Thalman obtained introspective reports of both "process" and "meaning." He improved the technique and apparatus used by Wohlgemuth. Although Wohlgemuth did not reconcile the negative outcome of his twenty-second experiment with his theoretical position, this is of no consequence. Wohlgemuth's two negatives really are equivalent to an affirmative.

Rubin and Weld (72) carried out a preliminary investigation of the Bourdon illusion. This illusion is strongly favored by the clock-wise rotation of the disc. A filmy grey, such as was reported by Dimmick in his study of the phi-phenomenon, was observed to be the correlate of the downward movement (rotation being clock-wise). However, there is a possible difference; for the grey of the Dimmick experiments did not change its position spatially, while the grey of the Rubin-Weld experiment may have moved. In respect to the differences between the two greys no conclusive results have been adduced. However, since the conditions in the two experiments were different, there is in all probability a difference in the phenomenal aspects. In the Rubin and Weld experiment there is real movement, while in the Dimmick study no objective motion occurs. There is a description of apparatus for demonstrating the Bourdon illusion. A disc of the size described by the authors suffices for a

demonstration before a group of 200. Professor Titchener has utilized the Bourdon illusion for the purpose of illustrating the results obtained by Dimmick.

Bates (3) investigated the Müller-Lyer illusion with special reference to paradoxical motion and the effect of attitude. Paradoxical movement between two members of the Müller-Lyer figure had already been studied by Koffka and Kenkel. A modification of the Dodge tachistoscope was used by Bates. The first part of the experiment consisted in an introspective investigation of content processes. It was found that the average extent of the illusion is less when it is "positive" than when it is "negative." The illusion is striking even when eye movements are eliminated and when the figures are almost completely in foveal vision. No single observer gives an invariable report of motion; one observer gives no report of movement whatever. The average amount of the illusion is 16 per cent of the standard length. Bates asserts that there is no physiological explanation at hand which would serve to show why the observed *Nebenreize* bring about a seen sensory movement without a corresponding displacement of the retinal image. Investigation of the influence of the totalizing and the analytic attitudes produced evidence to the effect that under both attitudes like psychological mechanisms were involved. The illusion does not merely consist in an inadequate statement of the problems. Movements and displacements are seen, not inferred. The illusion is not "psychological." "It exists as a pre-sensational and post-excitatory confluence of the central locus, dependent upon both stimulus and observational attitude for its realization." Adams (1) has investigated autokinetic sensations. Among other things there is given a historical review on this topic. The illusion was worked out for both monocular and binocular vision. Tests were instituted in order to determine how large a part was played by the factor of suggestion in controlling the direction of movement. Study was also made of voluntary control of the autokinetic movements, together with an incidental investigation concerning the effect of brightness degrees on the illusion. Fifty subjects were made use of incidentally, although the burden of the work fell upon four individuals. Two subjects found themselves able to gain voluntary control of the illusion. There were characteristic movements for the right and the left eyes, the movements in the case of the one eye being just the reverse of the movements for the other eye. Autokinetic movement perceived binocularly is not to be interpreted as the average or the resultant of two monocular

movements; for the movement is controlled first by one and then by the other eye. For distant objects the subjects were discovered to be right-eyed; for near objects they were left-eyed. The larger the source of illumination, the more serious the difficulty encountered in initiating the movement. Also, there is more pause and hesitation in the movement the larger the light. Ponderous, slow, and frequently pausing movements were conditioned by the largest lights. Suggestion is an important factor in determining direction of the movements; at least this is so for certain positions. The experiments show that during the time the illusion is being experienced a great strain is imposed upon certain sets of muscles. One of the evidences in favor of the "strain" theory formulated by Adams is that, when the eye is subjected to a great strain for the purpose of forcing it to move in a particular direction, the eyeball being maintained in a stationary position all the while, the illusory movements occur in the direction of the strain. Peterson (**63**) reported some striking illusions of movement of a single light on mountains, which are instances of the autokinetic illusion. The writer points out that the *ignis fatuus,* otherwise known as the will-o'-the-wisp, is probably due in large part, so far as its movements are concerned, to the factors involved in autokinetic movement. Certain of the movements perceived in the case of a single light on a mountain east of Provo, Utah, attained at times high velocities. When the movements were extensive they always took place in a more or less up or down direction. They quite disappeared when a sight was formed out of a near object, but were reinstated under ordinary, uncontrolled methods of observation.

Lewis (**56**) has investigated the illusion of filled and unfilled space. After a summary consideration of the theories advanced by Helmholtz, Hering, Lipps, and Wundt concerning the illusion in question, Lewis asserts the illusion to be markedly greater with momentary than with prolonged exposures. The illusion attains its maximum when there are about eight divisions of the given space. Practice in prolonged observation results in the disappearance of the illusion, while practice in momentary observation does not disturb its persistence. Prolonged observation results in a marked diminution of the illusion *providing the figure becomes unsymmetrical,* but decrease of the illusory effect is not significant under the condition of momentary observation. In the study by Smith *et al.* (**78**), data are collected relative to the influence of margins on the process of bi-section. When a margin is about one-half the length of the bi-sected

line the illusion practically vanishes; there is quite evident a restricted influence of the margin. The maximal effect is brought about by the use of a shorter margin. Flügel (24) has investigated the influence of attention in illusions of reversible perspective. When two reversible patterns are observed at one and the same time they fluctuate to some degree independently of each other. The modes of fluctuation are investigated by means of two juxtaposed, identical figures, by two unlike superposed figures, and by two different juxtaposed figures. The resulting data are maintained by Flügel to be incompatible with that type of theory which attributes reversals of perspective to physiological conditions (the Traube-Hering waves theory would be an example in point) that affect the entire central nervous system at the same time, and to run counter to the eye movement theory of reversals. Previous investigators have underestimated the part played by attention in the production of illusions of reversible perspective. In another study (25) Flügel brings forward some observations on local fatigue in illusions of reversible perspective. Use of the "revolving cross" or "windmill" illusion supports the observation of McDougall to the effect that a "prolonged period of binocular regard may produce fatigue of the aspect seen during this period, the fatigue being manifested in an unusually long period of the opposite aspect as soon as uniocular is substituted for binocular regard." Not all of Flügel's subjects, however, showed this fatigue. There is found to be considerable difference in respect to fatigability with different subjects. Some subjects show more marked fatigue with one aspect of the cross than with the other. There is some evidence to indicate that perception of direction of movement and perception of perspective are independently fatigable. The fatigue manifestations are not dependent upon whether they result in an increase of the "illusory" or of the "normal" perspective; moreover, they are independent of the amount of attention accorded the cross. No effect is produced upon them by the on-going of simultaneous mental processes during the period of the induction of fatigue.

Smith (77), in an experimental investigation on the prevalence of spatial contrast in visual perception, formulates three points. In the first place there is very little evidence, if any at all, to support the notion that contrast is usually operative in bringing about a modification of the length of a line. In this investigation Smith used parallel lines. However, certain data are at hand which might suggest that contrast operates in connection with such conditions as

confluence, for instance, and that such conditions tend to neutralize its effects. In the second place, the results obtained by the group of male subjects are to be more readily interpreted in terms of contrast, while the data derived from the group of female subjects are to be best interpreted in terms of confluence. Finally, the average length of the presented line is greater than that of the reproduced line, and this discrepancy is significantly greater for the men than for the women. Valentine (**86**) treats of various theories of the horizontal-vertical illusion. The contrast theory of the illusion is not valid for the reason that the illusion is as great for one eye as for both eyes taken together. Increase in the amount of the illusion is not necessarily brought about by increase in the magnitude of the lines. Lipps' theory of this illusion seems to be untenable, since no correlation exists between the tests on the horizontal-vertical illusion and tests upon another illusion that has, according to Lipps, a similar esthetic cause. Also, Lipps' theory is not in accordance with the fact that in the case of the "standing" vertical the illusion is on the average significantly less than in the case of the "hanging" vertical. The illusion was increased by practice in the case of three subjects. Valentine (**87**) has also investigated the effect of astigmatism on the same illusion, and has advanced a theory of the illusion. The horizontal-vertical illusion is not affected by astigmatism that does not exceed plus or minus 1.5 diopters, but astigmatism of plus or minus 2 diopters is sufficient to work an alteration in the apparent relative lengths of the lines. In view of the fact that the difference between the amounts of the illusion for the two eyes is sometimes larger than the entire amount of the illusion for one eye, it would appear that the astigmatic factor may be either the sufficient, or at any rate the principal, condition for the occurrence of the illusion. There were two cases in which the practice effect for one eye was greater than that for the other; in these cases the more efficient eye manifested the greater accentuation of the illusion with practice. Increase of the illusion under continued practice appears to be traceable to the setting up of a more "mechanical" attitude on the part of the observer, under the conditions of which he is more open to the immediate sensory impressions.

Stevens and Ducasse (**81**) investigated the connection between the retina and right-handedness. As a rule there occurs an overestimation of the right half of an expanse in the field of vision. This overestimation holds for both eyes. The retinal image of the overestimated expanse is formed on the left corresponding halves of

the retinas. The left corresponding halves of the retinas stand in an exclusive connection with the cerebral left hemisphere. For the reason that there exists a decided difference in the "space sense" of the two halves of the retina, objects occupying the right half of the visual field appearing to be larger than those objects occupying the left half, the attention is attracted to the right part of the field of vision and this leads to grasping movements of the right hand. Due to the fact that the right hand is from the first favored, it acquires special skill which leads to its use in those manual activities demanding greatest precision and efficiency.

Pintner and Anderson (64) tested adults and children with the Müller-Lyer illusion. This illusion, when used as a test for suggestibility, does not correlate with general intelligence as measured by chronological age. Increasing age carries along with it gradual decrease of the illusion, together with gradual decrease in the individual fluctuations; but neither of these decreases can be interpreted as being uniform. Binet thought that the illusion is "physiological" or "innate" because of the fact that the differences in the amount of the illusion between one age and any other age are not significantly large, and also because individuals within a given group evidence so large a variability. The findings of Rivers would serve to indicate that English university students are not, so far as this illusion is concerned, superior to such savages as the Murray Islanders and the Todas, although it would naturally be supposed that the Englishmen, on account of their formal training in things geometrical, would have been superior. The slightly larger amount of the Müller-Lyer illusion with the younger children may be explained as a matter of attention: attention is not so well directed upon the task in the case of the younger subjects, more carelessness is involved, and hence larger errors occur than in the case of the older observers. The larger average deviation of individual judgments in the lower ages bears out this supposition. Probably the three factors of experience, contrast, and attention converge in the production of this illusion, and increase the magnitude of the illusion with children. One of the inferences at hand is that the savages tested by Rivers were on a par with the Englishmen so far as the attention factor is concerned.

Henning (33) explains the phenomenal increase in the magnitude of the rising and setting moon and sun by reference to the fact that at such times of day longer light waves are predominant, and hence there occurs a clearer definition of objects. The moon, for instance, when on or near the horizon, is more clearly apprehended than at its

other positions and seems to be nearer to the observer and therefore of greater expanse. The experimental data presented by Henning are for the most part of a qualitative character. A considerable number of conditions are operative in this illusion; these are catalogued and discussed, and also referred to the laws mentioned in the title of the article. Wingender (**91**) uses a unique method for the investigation of such classical illusions as the Zöllner, the Hering, and the Müller-Lyer figures. The principal lines of these figures were illuminated through the use of reflected light, but the accessory lines were made visible through the application of transmitted light. Simultaneous illumination of both orders brought the figures to view as wholes. Striking changes were induced in the illusory figures by alternating the modes of illumination. Under the conditions of rapid alternation of illumination it was found that a minimal period of about one-quarter of a second is required for the development of the illusion. This is the temporal interval required for the change from a monocularly conditioned to a binocular stereoscopic perception. This time interval is certainly far larger than that necessitated for the mere sensory arousal. When the supplementary lines were added to the main parts of the figure by means of transmitted light, movement of the main lines was observed, and this movement served to generate the illusion. Facts are detailed concerning the relation between point of fixation, complexity, synthesis, and analysis, and the nature and amplitude of spatial illusions.

Bonaventura (7) presents an article that is concerned with the general scientific importance of the investigation of the optical geometrical illusions. Miller (**61**) has reviewed various theories which endeavor to explain the phenomenal alterations in the magnitude of the heavenly objects. Hornbostel (**39**) has investigated the illusions of reversible perspective and has presented a number of novel cases of the phenomenon. Lau (**54**), utilizing the Gestalt point of view, attempts to demonstrate that stereoscopic vision is conditioned by something more than a relatively simple functional interaction of retinal processes. The Müller-Lyer and the Zöllner figures are used. Apparent movement or distortion of aspects of the objectively static binocular structures was brought about by presenting real movement of a part of a configuration to one eye. An experimental illustration is as follows: Two vertical lines, made up of three black dots separated from each other by a small space, are presented to the eyes. If the upper dot in the left field is displaced to the right, then the midmost dot moves half as far as the uppermost dot; an oblique

line is the result of this procedure. The direction of this oblique line is toward the right, and the bottom dot forms the base of the line without being displaced from position.

Angell (2) reviews several theories of the horizon illusion, referring, *e.g.*, to the theories of Zoth, Guttmann, Helmholtz, Filehne, Reimann, Bourdon, Schaeberle, and Robert Smith. Zoth's crucial experiment was the test with darkened glasses; but several investigators, Reimann among them, have insisted on the delicate and difficult character of this experiment. The theory of Zoth, founded upon the concept of convergence strain, cannot be regarded as an ample support because of the investigations of Archer, Bappert, and Hillebrand on convergence and accommodation. Angell, in working on this problem, used the measurement of after-images projected to different altitudes. Stress is laid upon the complexity of the phenomenon. In general, the enlargement takes place with dark bodies observed against a lighter background, as is the case with landscape features and the "Brocken specters." But, acting on bright bodies, like the rising sun and moon, the possible enlarging effects of aerial perspective are so often rendered negative by other conditions that it is to be regarded merely as a subordinate and occasional influence in the production of the horizon illusion. Révész (69) performed experiments on animal space perception, using hens as subjects. Some of the well known geometrical optical illusions were used, such as the Jastrow and the vertical-horizontal patterns. The birds were given training series in which figures were used that possessed objectively different areas. The learning on the part of the bird in its response to the smaller of two patterns is interpreted partly in terms of the *Uebergangserlebnis* of Jaensch-Lindworsky. In the Jastrow illusion the animals reacted to the phenomenally smaller of the two segments. A crucial test is described in which three segments were used; two of these segments were objectively identical, while one was objectively smaller than the other two. This test proved to be remarkably successful, "the hen as a rule picking up the grain from the lowest figure first (the objectively smaller one), then passing on to the highest segment (the next subjectively smaller), leaving in the majority of cases the food on the middle segment untouched." Hens are clearly subject to the vertical-horizontal illusion. Some tests were performed upon young children from four to six years of age. *All* the children picked out the phenomenally smaller figure. Such a figure as that of Zöllner yielded negative results with the children. Révész draws the conclusion from all his work that the

extent and character of certain optical illusions cannot be significantly different for animals and children and for human adults. The work accomplished by Révész is decidedly against the judgment theory of the optical illusions. Furthermore, the work may throw light on the nature of the act of comparison. Warden and Flynn (**88**) have studied the effect of color on apparent size and weight. The color-size illusion is found to depend upon specific serial arrangement, and not upon the intrinsic quality of the color or upon the contrast effects of the immediate context. The color-size was of less extent than the color-weight illusion. The color-weight illusion takes place independently of the specific arrangement of the series; it is due partly to intrinsic color quality.

Pratt (**68**) has investigated the old problem of the visual estimation of angles. It was found that both obtuse and acute angles were as likely to be underestimated as to be overestimated. The angles considered typical were of 45 and 135 degrees. In the case of both acute and obtuse angles a tendency toward overestimation was displayed, but this tendency was insignificant numerically. In general, those subjects who overestimated obtuse angles likewise overestimated acute angles; one exception only to this rule occurred. Greater uniformity was found for the judgments of acute than for obtuse angles. Angular size was, in the by and large, judged not by directly forming an estimate of the amount of space between the two arms, but by judging the position of the arms in their relations to certain lines of an imaginary character. Through the medium of this judgment, inference was drawn as to the size of the angle. Luckiesh (**60**) has written a book that deals for the most part with the practical aspects of static visual illusions. The book emphasizes experimental facts and subordinates theory. The work is of particular value to all who are interested in the technological phases of light, color, and vision. There are chapters that are devoted to such applied problems as those involved in painting, decoration, architecture, and camouflage.

In the following footnote are the numbers of articles which have been reviewed by Professor Carr:

PSYCHOL. BUL., 1912, 9, 257–260: (84).
PSYCHOL. BUL., 1913, 10, 261–264: (4), (8), (12), (21), (22), (23), (73).
PSYCHOL. BUL., 1914, 11, 241–245: (30), (65), (66), (67), (80), (83), (94).
PSYCHOL. BUL., 1915, 12, 216–218: (17), (27), (28), (76), (85), (93).
PSYCHOL. BUL., 1916, 13, 265–266: (31), (32).
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SYNESTHESIA

BY HERBERT SIDNEY LANGFELD
Princeton University

In 1920, Wheeler (9) published a detailed description of the synesthesia of a blind subject. This paper was followed by a series of papers under the joint authorship of Wheeler and the synesthetic subject Cutsforth, which deal especially with the function of synesthesia in consciousness. In the first paper a description is given of the various forms of synesthesia possessed by the subject, who had lost his sight at the age of eleven. He had an extensive laboratory training and was a proficient introspector. Some of the forms of synesthesia were colored tones, music, alphabet, voices, proper names, names of the days, the months, the digits, the directions of the compass, colored number form, and colored forms for the week, month, century, and alphabet, colored odors, and cutaneous sensations, and colors for affective states, and for some of the emotional complexes. He also experienced colors for the imagery of tones, tastes, etc., which were the same as the colors for the respective sensations. Detailed description is given of the colors and their degree of permanence. The author ventures the hypothesis that synesthesia is "an immediate and permanent 'conditioned' reflex." The paper contains a good historical survey of the subject and an extensive bibliography.

Two years later Wheeler and Cutsforth (12) published an elaborate comparative study of the latter's (A) synesthesia with the experience of an asynesthetic blind subject (B). A is not totally blind, but his vision is confined to a form of entopic phenomenon. He describes his field of vision as filled with shifting colors and brightnesses. The color distribution corresponds to the retinal zones. The entopic phenomenon is probably due to inherent retinal light. He can distinguish these entopic colors, which are sensations, from the imaginal synesthetic colors. The authors discuss at length the process by which subject A is conscious of meaning. From a comparison of A's experience with that of B, it seems "that synesthetic imagery in A's case functions as an essential component in the

development of meaning. Synesthetic phenomena are themselves the development of meaning; they are acts of cognizing." For B, non-visual images come into the focus of consciousness upon a dominantly kinesthetic background, and as they then develop they become meaning. The functioning of the content of consciousness for the two subjects is the same; the mental contents, however, are different. The authors conclude that synesthesia is not due to an organic condition of the brain such as "tangling of fibers," but rather it is a normal and essential mental function for the subject, a cognitive process differing in no respect from any other process of meaning.

In a further paper (13) the authors develop more fully the rôle which synesthesia plays as a cognitive function in the life of the subject. They also describe the function of synesthesia in perception and in learning (11). In perception, the primary process is indescribable; it is merely a "something." Without the secondary process the observer cannot perceive. In the learning process, synesthetic phenomena appear in connection with the perception of the stimulus, and in retention, anticipation, immediate and delayed recall. In a short paper (10) the authors give a description of the subject's form and color imagery for numbers, dates, days of the week, and the months. In their latest paper (14) the authors have described the development of the concept on the part of the synesthetic subject. They performed experiments similar to those of Fisher (*Psych. Monog.*, 21, 1916) and found that the synesthesia is not confined to perceiving, but is also characteristic of conception. They confirmed Fisher's results, but desire to lay more emphasis than does Fisher upon the rôle of kinesthesis in the formation of the concept.

Cutsforth (2) reports an experiment upon the rôle of synesthesia in reasoning. The material used consisted of analogies, absurdities, simple and difficult abstract problems. The introspection of the synesthetic blind subject was checked against that of an asynesthetic, normal subject. Neither subject had imageless or non-sensory contents of consciousness. The results confirm those of the previous experiment described above. The subject's synesthesia is not an extraneous association. It is an essential factor of the process of comprehending meaning, and is both conceptual and perceptual in character.

English (4) has given a brief account of the experience of a child of three years, eleven months, who called soft music yellow, loud music black, and medium-loud music blue. The reason given

was that one cannot see yellow crayon marks on paper so well as black. The author suggests that from such reports it may be possible to discover the origin and development of color-hearing.

Azoulay (1) has described the case of an artist, who saw a white light every time she heard a sudden voice, if she happened to be in a dark place at the time. She did not, however, have color-hearing in the usual sense of the term.

Mudge (7) asked fifty students, most of whom were school teachers, to "report the colors, or brightnesses which they associate with certain tones, musical keys, instruments, and familiar musical compositions." Only eight persons reported lack of such associations. The author concludes that much of the visual imagery is due to particular experiences. High tones and high-pitched instruments are associated with bright colors, and low tones, and low-pitched instruments are associated with dark colors. There also seems to be a relation between timbre and richness of color and between purity of tone and the black-white series.

Wells (8) describes the nature and function of symbolisms, principally according to the views of Bleuler. He compares synesthesia with symbolisms, induced hallucinations, and autistic thinking. He also gives a number of examples from the literature of synesthetic experiences.

Winkler (15) has attempted a physiological explanation of synesthesia. He accepts the general theory of nerve conduction of Stöhr, which states that sensations occur in the periphery and that the impulse goes from there to the central neurones and thence to the various peripheral organs, both receptors and effectors. An acoustical stimulus can go to the central system and from there to the retina, causing a sensation of light. In this way he believes that synesthesia can be explained. The paper, which contains many references, supposedly in support of the theory, does not deserve further description.

Lundborg (6) has investigated the question of inheritance of colored hearing in three generations of a certain Swedish family. The father of the first generation, six children of the second and three of the first had colored hearing. The author concludes from these cases that colored hearing is probably a dominant Mendelian factor. It is not related to sex. The inheritance of other mental characteristics was also investigated.

Ginsberg (5) describes a case of synesthesia, where the stimulation of each of the sense organs produces secondary color sensations.

The subject also has photisms for digits and days of the week. Primary sensation blends often give corresponding secondary color blends. The author thinks that the association theory explains such phenomena as number forms, associations of colors with abstract terms, etc., but that we must seek a physiological explanation for "pure" synesthesia, such as colored hearing, colored tastes and odors, etc. He also believes that everyone has synesthesia in some form or other.

Donath (3) gives a complete description of a case of colored smelling. The associated colors, however, were not very constant. The subject also had colored hearing. The author describes the various theories and concludes that synesthesia is probably due to irradiation.

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HENRY J. WATT. *The Sensory Basis and Structure of Knowledge.* London: 1925. Pp. xi+243.

This book may count in the history of psychology as the "swan song" of structural psychology. The author—the late Dr. Watt, Lecturer on Psychology in the University of Glasgow—made systematic psychology his major interest. Over a period of nearly twenty-five years, until his recent untimely death, Watt's numerous experimental and theoretical papers, including his two major contributions, *The Psychology of Sound* (1917) and *The Foundations of Music* (1919), were directed chiefly upon the systematization of mental contents. The incentive and the careful methodology of Külpe and Stumpf, his two teachers, are evident in all his work, yet his own contribution was much more than a re-phrasing of what he had learned from them.

In brief, the system of psychology which is set forth in the volume under review is based upon sensation with its variable attributes. These attributes are: *quality, intensity, systemic position* and *extent, temporal position* and *extent.* While as a general rule each sense has its own unique quality, the other attributes are, with certain exceptions, common to all the senses, and serve as a means of integration. "We find," writes Watt, "good reason to believe that mind, like nature, is built on a coherent plan, and works in an orderly way. Or, being founded upon, or consisting of, certain elements, the integrations it shows flow from the nature and properties of these elements, and are therefore as systematic as the latter. The plans of mind are not those of the material system, to be sure. Nor can its actions be said to be merely mechanical. But they seem to share in that systematic coherence and rationality that in nature so gratifies our love of knowledge" (p. 74).

Given the elementary sensations of varying modality, the attributes, the capacity to fuse, and "the resulting conformations by summative overlapping are all that we need" in order to explain every integrative result. "It is evident that the whole nature of every figure is fully determined by the elementary sensations of which it consists, along with the distances that emerge from their more distant positions. This is the total *conformation* of the figure,

in which all the component elements are preserved without loss" (p. 79). In other words, configuration or *Gestalt* accrues to a sensory complex by virtue of the integration of its attributes.

In reading Watt's thorough and in many ways illuminating discussion of the principles of psychological integration, one is at every point reminded of the quite different approach to the same problem advanced in recent years by Wertheimer, Köhler, and Koffka. Watt's problem is the same as that of the *Gestalt*-psychologists, namely, the problem of synthesis. But beyond a few footnote references to Koffka's *Bulletin* article on "Perception," and to Köhler's *Physischen Gestalten* and *The Mentality of Apes,* no attempt is made to distinguish and evaluate the respective merits of these opposite interpretations. The reason for Watt's failure to justify his own thesis by comparison with *Gestalt*-psychology is perhaps accounted for by the fact that Watt's manuscript was completed some time before he found a publisher. At any rate, his two pertinent references to *Gestalt*-psychology—one to the "figure and ground" relation, taken from Koffka, and the other to Köhler's theory of adjustment of osmotic pressure on the part of the ions contained in two cerebral areas correspondnig to two sensations—give the impression of having been added after the original text was completed. However this may be, Watt, though obviously mindful of a rival interpretation of perception and thought, confined himself to the exposition of his own views. Despite this lack of defense against his rival, Watt's treatment of the subject is so cogent and so suggestive that no one interested in systematic psychology can afford to neglect it.

I have referred to this book as a "swan song" because it seems to close a period in systematic psychology. But I do not wish to appear unduly biased in favor of the rival interpretation of the *Gestalt*-psychology; for it, too, may pass as other theories have passed. The new orientation "from above," with its radical opposition to all methods like Watt's which start with unchanging elements, and find the clue to all conformations in the attributes of these elements, is only a logical *volte face*—an attempt to see what experience may look like from a radically different point of view. Illuminating as the results have been, it would be rash to assume that the *Gestalt*-hypothesis is more final than that of analytic structuralism.

Yet so far as present interest and research are concerned, one can say that a methodology based upon "elements" of whatever sort is fast losing ground. Behaviorism, phenomenology, psychoanalysis,

and recourse to the perceptions of common sense, are settling the problems and determining the methods of psychology to-day. Whether we shall ever turn back to the enumeration of sensory data and their attributive aspects, and be able to agree with Watt that the conformation of these "is not something new over and above the psychophysical aggregation that constitutes it" (p. 85), I cannot say; but if we do turn, it will probably be with a difference so marked that a reduction of perception and thought to sensory qualities with their "intensities," "volumes," "distances" will then seem to us a highly artificial method.

R. M. OGDEN

CORNELL UNIVERSITY

HANS HENNING. *Psychologische Studien am Geruchssinn.* Handb. d. biol. Arbeitsmethoden, Abt. VI, Teil A, Heft 5. 1926. Pp. 741–836.

In this paper Henning offers, so to speak, cream which he has skimmed from the psychological portions of the revised edition of his book, *Der Geruch.* As not all American readers know, this edition of 1924 not merely revises the work first published in book form in 1919, but greatly enlarges it and nearly reverses the order of topics. So much reading matter does this book contain that the psychologist who is not especially interested in smell should welcome this briefer presentation of its "reine Psychologie" as a ready means of learning or inferring Henning's opinions to date. He, however, has not written this paper to stress his own results or to press his own views, but has aimed rather at giving a comprehensive summary of the psychology of smell as it stands to-day. He has here done a piece of work analogous to that which he did for the *Ergebnisse der Physiologie* in 1919, and that work was well worth reading.

E. A. MCC. GAMBLE

WELLESLEY COLLEGE

H. ZWAARDEMAKER. *L'Odorat.* Paris: Doin, 1925. Pp. viii+299.

This book is virtually an abridgement and translation into French of the author's well known *Physiologie des Geruchs,* which reigned supreme as the authoritative work on smell from the date of its publication (1895) to the years of the Great War, when Henning began to publish his researches. The present book does indeed bring the physiology of smell briefly to date, but takes the slightest possible

notice of the work of Henning. The author's famous classification of odors (rooted in that of Linnaeus), and even his theory of the localization of the corresponding specific energies on the olfactory membrane from front to back, are again propounded, although according to Henning (cf. p. 832 f. of the paper of Henning noted in this issue of the BULLETIN) Zwaardemaker in more technical writing shows himself convinced that a one-dimensional classification will not answer. Nevertheless, his small treatise in French is admirably lucid and will be invaluable to the young and *post-bellum* psychologist who has neglected his German.

E. A. McC. GAMBLE

WELLESLEY COLLEGE

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NOTES AND NEWS

The Thirty-fifth Annual Meeting of the American Psychological Association will be held at the University of Pennsylvania, Philadelphia, Pa., on Tuesday, Wednesday, and Thursday, December 28–30, 1926, under the presidency of Harvey A. Carr of the University of Chicago. Scientific sessions will be held on the mornings and afternoons of each of these three days in the Psychology Laboratory, College Hall. The annual business meeting will be held on the evening of Tuesday, December 28, in College Hall; the annual dinner and President's address will be held on Wednesday, December 29, at the Hotel Pennsylvania, the headquarters of the Association. For information address the Secretary, Prof. Samuel W. Fernberger, College Hall, University of Pennsylvania, Philadelphia, Pennsylvania.